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OF THE

TYRONE DISTRICT, NEW MEXICO

BY

SIDNEY PAIGE

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1922

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and accompanying dikes. Groups 1, 2, and 3 are of probably late Cretaceous age.

4. Great flows of basaltic, andesitic, rhyolitic, and latitic lavas, with which are interbedded tuffs, breccias, sand, and gravel, in all aggregating several thousand feet in thickness.

5. Stocklike masses of fine-grained rhyolite and quartz latite porphyry, breaking through all the older rocks and through the lava flows just mentioned. Groups 4 and 5 are of Tertiary age.

6. Intrusive basaltic masses and basaltic lava flows interbedded with the Quaternary gravel.

Folding, faulting, extrusion, and intrusion have played important parts in the development of the geologic structure of this region. The principal structural features in the area are shown in figure 4.

The folding is decidedly open and is probably due in part to the forces that produced the faulting and in part to earlier igneous intrusion.

All the faults observed are of the normal type and express an extension or stretching of the strata. The strong northwesterly faults are probably parallel to and closely connected with broad axes of folding, for, broadly viewed, the fractures may be placed in two distinct systems, one trending northwestward and the other trending northeastward. The Silver City Range, for example, and its southeastern structural analogue, Lone Mountain, where not faulted along their eastern fronts, are sharply

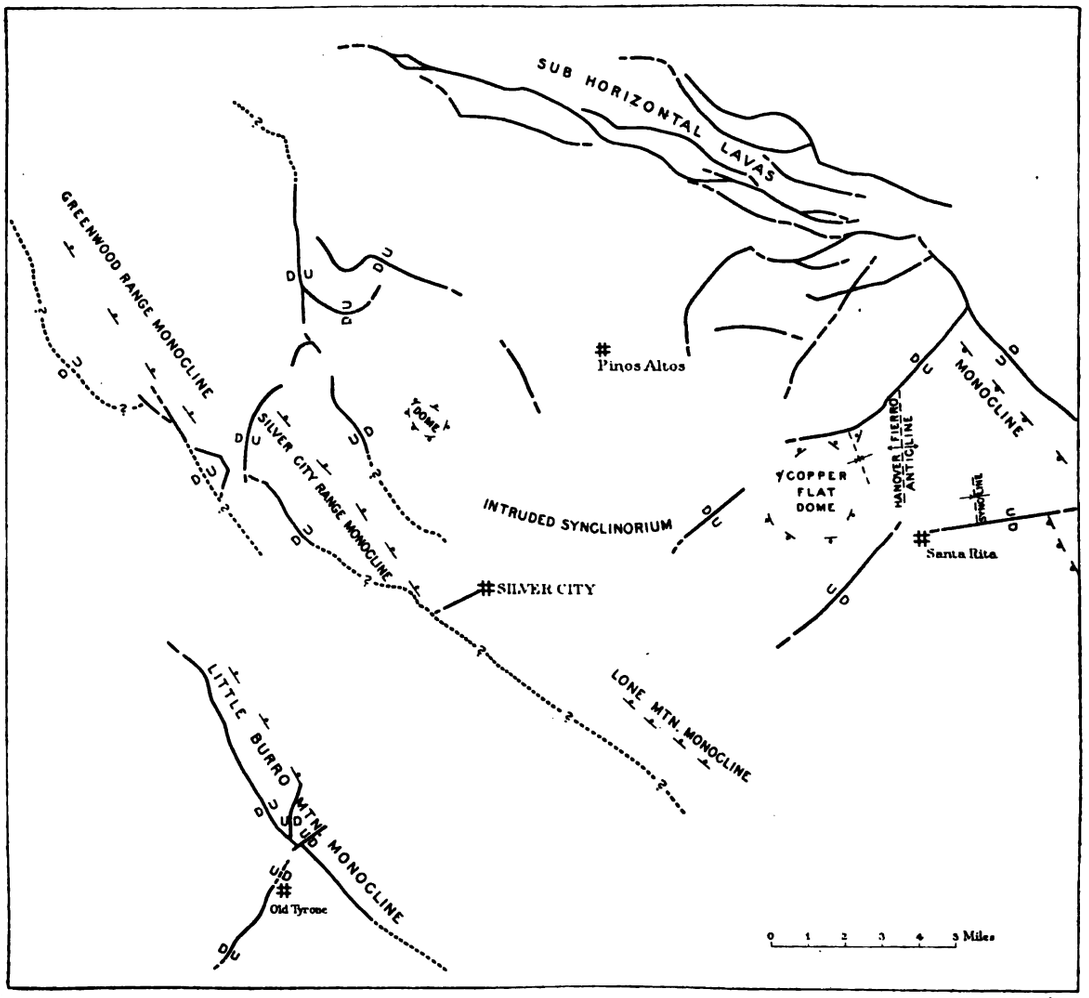


FIGURE 4.—Map of the principal faults and folds in the northern part of the Silver City quadrangle. D, downthrown side; U, upper side.

flexed, some beds standing at angles of 70° or more. West of these mountains, too, as is partly visible at Treasure Mountain and in the hills north of it, are strong faults nearly parallel to the fault on the eastern front.

The west flank of the Little Burro Mountains is also marked by a fault which is parallel to the monoclinal axis of the range. At Georgetown a strong northwesterly fault is parallel to the broad monocline that dips to the southwest.

In striking contrast to these widely separated dislocations are the closely spaced and on the whole much shorter transverse northeasterly fractures. These are well exposed in the Silver City Range. It is evident that almost every cross fault is downthrown on the north side (or uplifted on the south side). Such a system of faults involves a marked extension or lengthening of the entire block.

Several faults indicate rather certainly movements later than the period of Pleistocene deposition, though the recent movement on each of these faults was perhaps only a continuation of a much earlier disturbance. Such a fault is the one which separates the Pleistocene deposits from pre-Cambrian rocks at the western base of the Little Burro Mountains. Near the north end of this fault, a short distance south of Wind Canyon, the gravel beds abut against the rhyolite which with the overlying andesite forms much of these hills. (See Pl. III, *B*.) It does not seem possible that this attitude of the beds could be brought about by any other means than a fault. When this fault is traced southward to Redrock Canyon the abruptness of the contact of the gravel beds with granite is strikingly apparent. At the canyon, though the evidence that faulting has taken place is not perfectly clear, there are certain conditions which are rather opposed to a normal overlapping contact, the most significant of which is the fineness of the sediments that abut vertically against the granite. Although there is some granitic material in the gravel, the amount seems insufficient to establish a purely local origin for the pebbles. Furthermore, at a point about a mile north-northeast of Tyrone a cross fault offsets the straight fissure of the main fault. Both north and south from the cross fault the gravel contact for half a mile along the main fault is straight, but at the cross fault the contact is sharply offset for about 300 feet in a direction accordant with the dip of the fault planes and the throw of the cross fault. A short distance to the north of the point where the road crosses the main fault there is a vertical contact of fine gravel against broken rocks of the andesite complex, separated by about 3 feet of fault gouge. The gravel at the contact is not composed of material of the complex but of light-colored granite. Still another fact that may be cited is the difference in the character of the gravel contact on the two sides of the range. On the east it is much higher than on the west, and the gravel lies upon an irregular surface of rhyolite with a crooked contact and shows very coarse material at the base, the conditions presenting a marked contrast to those on the west side.

Similar evidence of post-Pleistocene faulting may be seen at several other localities north of Treasure Mountain and east of Georgetown.

The age of movement along a plane or surface of weakness is difficult to determine, for where a break has once been formed by movement a continuation of the movement is likely to take place, perhaps at intervals, through a long period of time. It is therefore impossible to determine definitely when faulting first began in this area. It is evident that faulting has taken place since the deposition of the Pleistocene gravel and that some faults break the Tertiary lava flows without apparently affecting the Pleistocene gravel; but though no fault was found that cuts Cretaceous rocks and does not cut Tertiary lavas, yet faulting might have begun before the lavas were deposited and continued along the same planes after their deposition. The absence of any direct evidence pointing to this conclusion, however, permits the tentative assumption that faulting began after the lavas had been poured out and continued at intervals along certain breaks after the deposition of Pleistocene gravel.

GEOLOGIC HISTORY.

PRE-CAMBRIAN ERA.

The ages that preceded Cambrian deposition doubtless comprised many periods of sedimentation, erosion, and disturbance, covering in all a longer time than that represented by all succeeding geologic history. Only the merest fragments of this history can be read in this area. The pre-Cambrian rocks are largely granites, in which are enmeshed the

almost indistinguishable traces of sedimentary deposits. A few small areas of quartzite and schist point to the existence of ancient seas. The metamorphosed and fragmentary character of these sedimentary rocks shows that their history has been varied.

There is abundant reason to believe that old mountain ranges existed in this region and that the forces of erosion in the past, even as to-day, carried on their work of denudation. The character of the surface upon which the earliest Cambrian strata rest serves to corroborate what has been observed at many other localities, namely, that a prolonged period of erosion and planation preceded the subsidence of the pre-Cambrian land beneath the sea to form a floor of moderate relief on which the Cambrian sands were deposited.

PALEOZOIC ERA.

The nature of the basal Cambrian strata, which are composed of quartzose, calcareous, and glauconitic material, shows that at the time of their deposition the sea was gradually transgressing upon a land surface of moderate relief. It is probable that as the sea advanced wave action reduced still further a rather low relief, and that the remarkably flat contact between the Cambrian sediments and the pre-Cambrian basement is in part a result of this action.

The subsidence whose beginning is marked by these Cambrian beds endured for a long period. As the seas gradually grew deeper or as the shore line slowly transgressed landward, calcareous sediments gradually became more prevalent, and finally they formed the only record of deposition. Though these seas were not deep they were probably extensive. Whether the interval of time indicated by the differences between the fauna of the Bliss sandstone and that of the El Paso limestone includes a period when Cambrian beds were raised above sea level and subjected to erosion can not yet be determined. Apparently there was a rather abrupt transition from the sandy limestone layers of the older formation to the more calcareous beds of the younger formation, but if there is an unconformity between the two formations it has not been detected. The incursion of sandy material in the upper part of the El Paso limestone marks the unsettling of a delicate balance of depth rather than any great uplift. The quartz sands found in this part of the Cambrian system may have been carried there by currents that swept across wide areas of shallow seas or may in part have been blown from neighboring beaches by violent winds, for limestone deposits may be formed close to the seashore provided great quantities of débris are not being contributed to the sea.

The record of Silurian time, with its fossiliferous and chert-bearing beds, shows that the conditions then were similar to those of the preceding period, but the abrupt change from Silurian limestone to Devonian shale suggests a fundamental difference in conditions of sedimentation. Though the bedding of the Silurian limestone and the Devonian shale seems to be concordant, there is reason to believe that the beginning of Devonian deposition was preceded by marked erosion in this southwestern area. At Bisbee, for example, as stated by Ransome,[9] Devonian beds rest upon Cambrian limestone; at Clifton, as shown by Lindgren,[10] Devonian beds overlie Ordovician beds; and in the Silver City region Devonian beds rest upon Silurian beds. These facts and the sudden change in sedimentation marked by the deposition of Devonian shale on Silurian limestone point to decided irregularities in the Paleozoic sequence in this southwestern province, probably indicating a period of uplift and erosion.

The gradual change from shale to limestone observed at the top of the Devonian Percha shale indicates an uninterrupted period of deposition between Devonian and Carboniferous time and a decided clearing of the seas. The faunal changes are likewise noteworthy. The muddy waters in which the upper part of the Percha shale was laid down seemed especially adapted to Devonian forms, but when the waters became clearer they no longer afforded a suitable habitat for the Devonian fauna, which therefore disappeared and was succeeded by Carboniferous forms. No stratigraphic break has been detected between the Mississippian and Pennsylvanian beds, though differences in the fossils of these series suggest such a break.

[9] Ransome, F. L., U. S. Geol. Survey Geol. Atlas, Bisbee folio (No. 112), p. 12, 1904.

[10] Lindgren, Waldemar, U. S. Geol. Survey Prof. Paper 43, p. 59, 1905.

MESOZOIC AND CENOZOIC ERAS.

After the quiet of the Paleozoic seas came the gradual emergence of a Mesozoic continent. No evidence is at hand to prove that the uplift was accompanied by notable structural disturbance. No certain pre-Cretaceous faults are recognized, nor has any folding been observed that might not be assigned to later periods. It must be inferred, therefore, that although the emergence was widespread, it took place in this area without other deformation than gentle warping and tilting. That the tilting may have been appreciable is shown by certain relations between the basal Cretaceous beds and the underlying Paleozoic rock. For example, the Beartooth quartzite shows a remarkably clean-cut flat surface at its base, especially on the summit of the Little Burro Mountains, suggesting a decided leveling of the underlying floor. Now, as the basal Cretaceous beds were deposited on Pennsylvanian, Mississippian, Devonian, Silurian, and pre-Cambrian rocks, it may be inferred that these old rock beds were tilted during their uplift and their edges eroded nearly to base-level.

The absence of Triassic or Jurassic strata beneath the Cretaceous sediments points either to the existence of a continent during Triassic and Jurassic time or to an even longer period of denudation than has just been inferred.

The accumulation of Cretaceous sandstone, shale, and calcareous shale to a thickness of probably several thousand feet followed the subsidence of this eroded land surface. The quiet sedimentation, however, may have been interrupted by subaqueous outbursts of andesitic and allied volcanic material. The breccias of the andesite-diorite complex have here and there the appearance of sills, being both underlain and overlain by shale; but as the pyroclastic nature of the breccia precludes an intrusive origin, it is suggested that near the end of Cretaceous sedimentation, or after it had ceased, volcanoes added their quota of material to the marine Cretaceous accumulations. The apparent sill-like relation observed may, however, be due to faulting.

There is abundant evidence of intense igneous activity from this time on. Thousands of dikes cut both the Cretaceous shale and the breccias, indicating that the outbursts which furnished the pyroclastic accumulations were followed by continued long-extended fracturing of the strata and concomitant filling of the fissures with igneous material. The great preponderance of this complex in the Cretaceous rocks suggests that a center of volcanic activity existed somewhere near or north of Pinos Altos, though there may have been subsidiary centers near the Little Burro Mountains.

The next period was notably different from the long period of sedimentation above described. No evidence that the land was ever again beneath the sea has been found, but there is conclusive evidence that no less than five stages of intrusion succeeded the one already described and that they were associated with notable structural dislocations.

The product of the first of these intrusions was rock of the quartz diorite porphyry type, which is well developed around Fort Bayard and extends southward and eastward from that point. This intrusive takes the form of a sheet at some places—for example, at Fort Bayard, where it lies above the Cretaceous sediments and dips westward with them. Farther west it dips beneath the Colorado shale. Moreover, it follows regularly the nose of the domelike uplift of which Copper Flat is the center. It is rather hazardous to correlate intrusive masses by lithologic features alone, but it is believed that the intrusives west of the Kneeling Nun, at Hermosa Peak, and near Lone Mountain are of the same date as the laccolith just described.

Next in order of intrusion are such masses as the granodiorite between Hanover and Fierro, the masses at Copper Flat, Santa Rita, Pinos Altos, Gomez Peak, and Silver City, and the quartz monzonite mass of the Big Burro Mountains. That the mass between Fierro and Hanover and the mass at Santa Rita are later than the Fort Bayard intrusive mass is suggested by the presence in the Fort Bayard laccolith of dikes very similar in composition and general aspect to the Fierro mass. The intrusion of these later crystalline porphyries is of structural importance in that their entrance through the overlying rocks domes up the otherwise undisturbed beds. The masses at Copper Flat, Hanover, and Gomez Peak, for example, clearly illustrate such action. When these bodies of igneous rock, whose great surface exposure probably only indicates a still greater subsurface extent, had cooled, there

ensued a period of active erosion, which is clearly indicated by the fact that such masses as the granodiorite of Pinos Altos, which must have cooled under considerable cover, probably 1,000 feet or more, were exposed at the surface before the outpouring of the broad floods of lava that overlap them on the north. At Pinos Altos, for example, the granodiorite passes beneath the lava cover, and the surface outcrop at the veins which cut the granodiorite is abruptly terminated by the overlying glassy rhyolite.

Little imagination is required to picture the conditions that must have existed at the beginning of this epoch of volcanic activity, which closed the Cretaceous period. There is evidence that violent explosions preceded the welling out of the vast floods of lava and that torrential rains distributed the material of the breccias and tuffs over the uneven surface of the land. Here and there lakes were formed, into which fell the dust and the coarser ejectamenta from the active volcanic vents. Such coarse and fine accumulations are well exhibited in the region north of Lookout Peak, and the finer sediments and gravels at the base of the lava series may be seen at many places, notably east of Lone Mountain and north of it along the scarp that forms the edge of the lava floods in that region.

Then followed, in Tertiary time, the eruption of great sheets of rhyolite or latitic lava, covering hills and valleys alike and obliterating the older landscape, which the earlier explosive accumulations had modified.

After these outbursts of rhyolite-latite, which in places aggregated 800 feet in thickness, there were floods of andesitic or basaltic lava, which in time were followed by more siliceous lavas. Indeed, an alternation of the two kinds is a marked feature of these accumulations. Between the outbursts of lava there accumulated local deposits of fine sand and tuff, the detritus washed from the more elevated portion of the deposits to the basin-like areas which must have been formed in such a chaos of molten flowing material. These sediments attain considerable thickness in places but are generally thin at the edges and disappear, permitting the overlapping of successive lava floods. Such thinning out of interbedded clastic material is well shown in the range east of Lone Mountain and in the area farther north, adjacent to Black Peak.

As if in adjustment of the enormous disturbance of equilibrium that must have been caused by the flooding of this broad territory with lava and of the shifting of so large a mass of material from beneath the surface at one locality to the surface of the crust at another locality, faulting was renewed and has continued, probably with interruptions, up to the present time. This faulting was attended by the intrusion of many stocklike masses of latitic material that cut through all the underlying strata alike from the pre-Cambrian complex to the latest lavas. During this stage of faulting the present higher parts of the Silver City Range and Lone Mountain were probably outlined, and Bear Mountain was formed by the intrusion of the stocklike mass that constitutes its core. Then, too, the Little Burro Mountains assumed or began to assume their monoclinal attitude, and the region around Santa Rita was broken by faults. At this period also the lavas farther north were sliced into numerous narrow curving fault blocks, and the region north of Stewart Peak was faulted and intruded.

The remaining changes that have affected the area are due principally to erosion and concomitant deposition and to sporadic outbursts of basaltic lavas. Widespread deposits of Pleistocene gravel accumulated in the already maturely dissected valleys, and on this gravel thin basaltic lava flows were spread, to be later covered by still more gravel.

GEOLOGY OF THE TYRONE DISTRICT.

ROCKS.

All the hard rocks exposed in the Tyrone district are igneous intrusives. Semiconsolidated gravels cover several square miles, but drilling through these superficial deposits has revealed no ancient sedimentary terranes.

The igneous types recognized in mapping are granite, quartz monzonite and quartz monzonite porphyry, quartz latite porphyry, aplitic dikes, and rhyolite dikes. The distribution, petrography, and structural interrelations of these types will be described in turn, after which the structure, metamorphism, and physiography of the region will be discussed.

GRANITE.

Distribution.—Granite occurs in the southeast corner of the district over an area of

about 5 square miles; in the southwest corner, forming the higher portion of the Big Burro Mountains; and along the northern border, in a strip about 1¼ miles wide. It also forms a number of isolated masses near the center of the area and near the eastern gravel contact in secs. 26 and 27, T. 19 S., R. 15 W., where it is surrounded by quartz monzonite porphyry.

Petrography.—The granite of the Tyrone district is not a single homogeneous mass but includes a number of varieties exhibiting differences in texture and slight differences in mineralogy.

For the most part the granites are medium to coarse grained holocrystalline rocks ranging in color through gray and pink. They are composed dominantly of quartz and orthoclase feldspar, with some oligoclase feldspar. Biotite mica, though not generally a conspicuous mineral, is present in many places. The common accessory minerals, iron oxide, apatite, and zircon, may be noted.

A coarse-grained variety near Sugarloaf Mountain is gray and contains prominent pink feldspars. Abundant biotite is plainly visible.

The Big Burro Mountains are composed of a medium-grained gray granite consisting of orthoclase, quartz, and a little oligoclase, with biotite. A semblance of porphyritic structure is caused by scattered orthoclase feldspars larger than the average crystals of the rock.

In Deadman Gulch below the road crossing, west of Leopold, there are a number of varieties of medium to coarse grained granite, among them one containing prominent pink orthoclase feldspars set in a matrix of gray feldspar and quartz. The scarcity of ferromagnesian minerals is striking.

In the southeast corner of the district there are wide areas underlain by pink medium-grained granite that is generally lacking in ferromagnesian minerals, but this lack is due partly to alteration.

As a whole the granites are characterized more by their variation from place to place than by uniformity of appearance. Undoubtedly a number of distinct invasions have taken place in pre-Cambrian time. No attempt was made to unravel the complexities of these intrusions.

QUARTZ MONZONITE AND QUARTZ MONZONITE PORPHYRY.

PRINCIPAL MASS.

Quartz monzonite and quartz monzonite porphyry form the largest single rock unit of the Tyrone district. This unit is a roughly circular intrusive stock cutting pre-Cambrian granite. A small portion of its contact lies beyond the area shown on the map. Quartz monzonite porphyry also occurs in dikes, many of which are too small to be mapped.

Distribution.—The main mass occupies a central position in the area, where it covers about 15 square miles, or about half the total area. Its contacts with the invaded pre-Cambrian granite are for the most part easy to locate and follow. There are places, however, where the distinction between the two rocks is not so plain. Several conditions account for this obscurity. First, within the pre-Cambrian granite complex are rocks of granitic types that closely resemble the quartz monzonite, particularly where the two rocks are weathered and have undergone partial disintegration. At such places, though the contact may not be precisely located, by studying the contact region it can be shown that unmistakable granite is close at hand, because the granitic terranes as a whole are not homogeneous, whereas quartz monzonite and its porphyritic phases on the whole are homogeneous to a high degree This is a good criterion on which to distinguish the two groups in the field.

Another source of difficulty is occasioned by the presence of small outliers of pre-Cambrian granite within the main monzonite mass—small slivers and blocks broken off at the contacts. This feature, however, is a minor one in the Tyrone district.

A third difficulty arises in the fact that irregular aplitic dikes are present in some places both in the granite and in the quartz monzonite porphyry, and where this condition exists along a contact precise boundaries are not readily established.

The main north contact runs eastward from the western border of the district to a point about a mile south of Tyrone. This contact, from the western edge of the district to St. Louis Canyon, passes along the southern slope of a number of hills—that is, the porphyry is

eroded to a lower level than the invaded granite. From St. Louis Canyon eastward, however, there is no such difference in degree of erosion. In this area both rocks are silicified and mineralized. These features will be discussed under the heading "Physiography" (pp. 19–22).

The contact passes beyond the area mapped on the western border and enters it again to skirt the base of the Big Burro Mountains. It also passes from and reenters the area on the southern border. The boundary on the east side of the Big Burro Mountains is in places buried beneath granitic débris, swept over the contact.

It is possible that inclusions of granite smaller than those mapped may be present and have been overlooked, as the rock in much of this territory is highly metamorphosed. The occurrence of such blocks is, however, of no economic importance, as will be shown below.

Petrography.—The main mass of quartz monzonite porphyry contains a number of textural varieties. These are (1) rocks of granular texture and properly not porphyries, (2) porphyries characterized by large orthoclase phenocrysts (as much as 3 inches in length) and prominent quartz phenocrysts, in many places doubly terminated by pyramid faces; and (3) porphyries in which the orthoclase phenocrysts are intermediate in size or are no larger than the other feldspar phenocrysts of the rock.

Field studies indicate that the change from type 2 to type 3 takes place on the north rather abruptly along a roughly east-west line (see Pl. II, in pocket), but that on the south the two types are transitional into each other. Along the northern line no intrusive contact was seen, and it is concluded that the change is due to physical and chemical factors governing crystallization.

The granular type of quartz monzonite is a medium-grained rock of gray color containing abundant biotite. It is composed predominantly of oligoclase feldspar and quartz, with a minor amount of orthoclase feldspar. In places it contains considerable light-green hornblende. Titanite, apatite, and iron oxide may be present. The rock might equally well or perhaps better be named a granodiorite.

The porphyritic type, characterized by large orthoclase feldspars, resembles the granular types in that it contains abundant biotite and though of porphyritic texture has nevertheless, where medium to coarse grained, a somewhat granular appearance. It differs in carrying conspicuous large phenocrysts of pink feldspar and abundant smaller phenocrysts of quartz, and many of the latter are crystallized as double pyramids joined by short prism faces. The spacing of the feldspar phenocrysts and the abundance of the quartz phenocrysts vary considerably from place to place—they may be separated by only a few inches, or there may be several feet between individual phenocrysts, and locally they are entirely absent. The phenocrysts vary in size also and in places are hardly more prominent than the other minerals of the rock.

The phenocrysts may be either oligoclase feldspar, quartz, or biotite, set in a granular groundmass of varying degrees of fineness, consisting of quartz or orthoclase. Many of the quartz phenocrysts show resorption phenomena.

DIKES AND SMALL MASSES OF QUARTZ MONZONITE PORPHYRY.

Dikes and small masses of quartz monzonite porphyry occur both as offshoots from the main mass and as later dikes cutting through the main mass.

Several of these later dikes have been mapped. Two near the northern border of the district have been traced for more than 3 miles. For a considerable distance they are approximately parallel, but they diverge noticeably at their east ends and are not everywhere continuous at the surface. The southern dike at its east end is very thin and can not be located with certainty, but float and small outcrops indicate its presence.

Dikes of similar character are found to the south, in secs. 26 and 27, and similar rock, intensely altered, occurs in secs. 10 and 15. These dikes are characterized by abundant large idiomorphic phenocrysts of feldspar and quartz. Many of the quartz crystals retain their crystal faces, and in places as many as six intergrown so as to constitute a single quartz phenocryst were noted. The number and size of these prominent minerals vary from place to place. Biotite is present, though not conspicuous.

The main body of the rock consists of smaller phenocrysts of oligoclase in a very fine grained groundmass of quartz and orthoclase. There

are many quartz phenocrysts within these rocks, besides those displaying well-developed crystal faces, which show marked absorption phenomena. Their surfaces are corroded and rounded and in places deeply embayed, and reaction rims of the quartz and feldspar of the groundmass surround them. It is possible that some of the corrosion took place during the injection of the dikes. On examination with the microscope it becomes evident that much sericite has formed, both as disseminated flakes in the feldspar and completely replacing the biotite.

A small mass of porphyry cutting the granite in sec. 35 is different from the common porphyry of the district. It is finer grained, and fresh specimens have a brownish color. Small biotite and feldspar phenocrysts may be made out with the naked eye, set in a sugar-grained groundmass somewhat resembling a fine-grained sandstone. The microscope shows phenocrysts of oligoclase and biotite with some light-green hornblende, in a fine-grained groundmass of quartz, oligoclase (in rods), and some orthoclase. The rock is without question closely related in chemical composition and probably in date of intrusion to the main mass of porphyry.

APLITIC DIKES.

Some of the aplitic dikes are allied with the pre-Cambrian granites, and others with the quartz monzonite porphyries. Such rocks are characteristically developed with acidic intrusives and represent the more siliceous portions and latest injection of the magma. Within the pre-Cambrian granites notably, and in the quartz monzonite porphyry to a lesser degree, they are associated with pegmatitic facies of the main masses.

These dikes have nowhere been mapped on the surface and are considered simply as an abnormal development of the main masses.

The aplitic dikes and masses are characteristically irregular in form and both on the surface and in the mines have very irregular boundaries. Along the main contact between Leopold and the gravel sheet these dikes and masses occur and in places made it difficult, especially where surface débris is plentiful, to locate the porphyry contact. North of the main contact, too, in this general area, the granite is broken by narrow dikes and masses of this rock, a confusing condition in an area where the rocks are so intensely metamorphosed. It was not practicable to map them.

The aplites are fine-grained rocks of pinkish-white color, composed of orthoclase and quartz in about equal amounts, with a little biotite and in places evenly dispersed iron oxide. Locally the quartz and orthoclase assume a rude micrographic texture. Very small phenocrysts of quartz appear here and there.

RHYOLITE DIKES.

Rhyolite dikes are not abundant within this area. A few, the more prominent, have been traced and mapped in the northwest corner of the area, and one is shown in sec. 35. These dikes are very numerous to the south, beyond the confines of the area under consideration.

The rhyolites are fine-grained white rocks of somewhat porphyritic character. Under a hand lens small phenocrysts of orthoclase and quartz and small biotite crystals are plainly visible, set in an aphanitic groundmass, which proves on examination with a microscope to consist of orthoclase and quartz, at least locally showing micrographic intergrowth.

These rocks are of later age than other intrusives of the district, but it is not possible to assign to them a précise date of intrusion, as it is known that several periods of volcanic activity occurred in post-Cretaceous time.

QUARTZ LATITE PORPHYRY.

Quartz latite porphyry occupies a small area in the extreme northeast corner of the district. It is part of a larger area of such rock that forms the south end of the Little Burro Mountains.

The metamorphism, however, is here so thorough that it is not possible to affirm positively whether the rock is of the same age or younger than the quartz monzonite porphyry at Tyrone. The latter conclusion seems the more probable; and the rock is therefore correlated with the later Tertiary intrusions of other parts of the Silver City area.

SEMICONSOLIDATED GRAVEL AND SAND.

The Tyrone district borders a region made up of large areas of semiconsolidated sand and gravel. Portions of these deposits occur within

the district, principally in the northeastern part and along the northern border.

Character.—The material of these deposits is derived from the neighboring mountains and consists of fragments of lava or of pre-Cambrian igneous rocks or younger sediments, its character depending upon the kind of rock that is exposed in the adjacent uplands. The fragments range in size from fine dust to blocks several feet in diameter. In some places large boulders form a part of the deposits. Most of the fragments are subangular, as would be expected in view of the proximity of their source and the mechanical nature of the rock disintegration by which erosion was aided in Pleistocene time, as it is at present.

Calcite, silica, and iron oxide, alone or combined in differing proportions, are the cementing materials which in places bind together the otherwise loosely collected fragments and make of them a resistant conglomerate.

Relation to underlying surface.—The contact of the gravel about the Big Burro Mountains is apparently a normal depositional contact. That the gravel formerly covered parts of the foothill region which are now bare and that it has been carried outward to its present position during a period of recent dissection seem certain. How much of the Big Burro Mountains was covered is indeterminable, but a well-defined rock bench that occupies at least much of the north and east sides of these mountains is plainly visible from any high point on the Little Burro Mountains. Probably gravel once covered this bench, but presumably the main mountain core was never covered and in fact was the source during Pleistocene time of much of the gravel that now surrounds the mountains.

In the Little Burro Mountains the conditions are somewhat different. The gravel contact along their east side is normal and follows the crest of the eastern ridge of the mountains, but for much of its length the contact on the west side is along a fault and lies at the base of a more or less precipitous mountain scarp.

Age and correlation.—Gilbert [11] in 1873, while studying the region drained by the upper Gila and its tributaries, gave the name Gila conglomerate to certain valley deposits which he described as follows:

> The boulders of the conglomerate are of local origin, and their derivation from particular mountain flanks is often indicated by the slopes of the beds. Its cement is calcareous. Interbedded with it are layers of slightly coherent sand and of trass and sheets of basalt, the latter, in some cliffs, predominating over the conglomerate. One thousand feet of the beds are frequently exposed, and the maximum exposure on the Prieto is probably 1,500 feet. They have been seen at so many points, by Mr. Howell and myself, that their distribution can be given in general terms. Beginning at the mouth of the Bonito, below which point their distinctive characters are lost, they follow the Gila for more than 100 miles toward its source, being last seen a little above the mouth of the Gilita. On the San Francisco they extend 80 miles, on the Prieto 10, and on the Bonito 15. Where the Gila intersects the troughs of the Basin Range system, as it does north of Ralston, the conglomerate is continuous with the gravels which occupy the troughs and floor the desert plains. Below the Bonito it merges insensibly with the detritus of Pueblo Viejo Desert. It is, indeed, one of the "Quaternary gravels" of the desert interior and is distinguished from its family only by the fact that the watercourses which cross it are sinking themselves into it and destroying it, instead of adding to its depth.

The Pleistocene deposits in the Silver City quadrangle correspond to the Gila conglomerate in all important features. Gilbert, followed by Ransome, assigned an early Quaternary age to the Gila conglomerate. Fossil bones are reported from the gravels south of Santa Rita, but none were seen by the writer. There is no reason, therefore, to assign to the beds an age other than that already suggested.

STRUCTURE.

As all the rocks of the Tyrone district, except the gravels, are massive intrusives, their structural relations have to do wholly with intrusion, faulting, and fracturing. Folding plays no evident part in their interrelations.

INTRUSION.

The main stock of quartz monzonite porphyry intrudes a granite complex and is subcircular in its outcrop. There is some evidence that on its northern border it dips to the south. At other places no clue has been gathered as to the attitude of its walls—whether converging or diverging downward. Offshooting dikes from the main mass indicate that fracturing of the invaded rock played a part in permitting the entrance of the magma. Whether or not stoping of the wall rock has taken place on a large scale is undetermined. On the southern contact in secs. 3 and 34 a

[11] Gilbert, G. K., U. S. Geog. and Geol. Surveys W. 100th Mer. Rept., vol. 3 p. 540, 1875.

A. FAULT CONTACT BETWEEN GRANITE AND GRAVEL IN ST. LOUIS CANYON.

B. QUATERNARY GRAVEL FAULTED AGAINST RHYOLITE ALONG THE EAST SIDE OF MANGAS VALLEY.

long tongue of porphyry projects at a low angle, nearly parallel with the contact, into the granite, nearly isolating a slice of that rock. Should such a block of granite have been entirely severed from its parent mass, it might possibly have sunk into the magma. The detached island-like masses of granite in secs. 22, 27, and 26 may represent remnants of a roof, in place, or may connect downward with the main granite mass. The writer found no certain evidence on which to base an opinion regarding these points.

A number of dikes cut the granite and the quartz monzonite porphyry. Structurally they suggest that the region was still under the influence of tensional stresses after the larger intrusions had solidified. This suggestion is accordant with the evidence afforded by the faulting and fracturing.

FAULTING.

REGIONAL FAULTING.

Faulting has played a very important part in the dynamic history of the region about Tyrone. Reference to figure 4 (p. 6) will show that there are two principal fault systems, one having a northwest to west-northwest trend, the other a northeast trend. The close spacing of the northeast breaks indicates the completeness with which the ground was fractured, and when it is borne in mind that there are many fractures not shown a fair impression is gained of the thoroughness of the process of dislocation. These two dominant fault systems are, it is believed, connected in origin with movements of folding. The evidence supporting this belief has been given in the Silver City folio, on the maps of which the relation of faults to folds is made clear. It is reasonable to suppose that a broad syncline whose axis passes northwestward between Silver City and Santa Rita is but one of several similar broad folds. (See fig. 4.) So conceived the region about Tyrone would fall somewhere on the eastern limb of a broad anticline, upon the details of which, for lack of data, it is futile to speculate.

It is believed that the formation of such a system of folds accompanied widespread uplift and intrusion and that gravitative adjustment, accompanying or succeeding such distentional movements, accounts for the faulting that ensued. That the movement of uplift was such as would produce distention is suggested both by the normal character of the faults and by the vast amount of igneous material that has entered the rocks, particularly during Cretaceous time. There are wide areas filled with narrow dikes. Only the distention of the crust could have made possible this great influx of magma; and it is not surprising that such a process should result in the instability of individual blocks. Both during and after such an uplift faulting would take place on a great scale. The cause of such widespread uplift may well be connected with igneous injection even if not controlled by it. The primary cause must be sought in the realm of the theory of earth physics. It is a fact that in the Silver City region igneous invasion accompanied uplift, and beyond this important fact it is here not necessary to go.

FAULTING IN THE TYRONE DISTRICT.

Of the larger northwestward-trending breaks one that forms the western scarp of the Little Burro Mountains crosses the Tyrone district. This fault tilts the pre-Cambrian rocks of the Little Burro Mountains and the overlying Cretaceous sediments toward the east, and it may be presumed that the rocks west of the fault, which are relatively downthrown, are also tilted eastward. There are certain facts which support this presumption. Two of the faults of the northeast system (see fig. 4) if continuous southwestward across the Mangas Valley must enter the Tyrone district a short distance west of Tyrone. There is field evidence to support the view that they are thus continuous. The contact between gravel and pre-Cambrian granite from St. Louis Canyon northward for half a mile is a fault contact. Both at the road crossing where the relation is evident (see Pl. III, *A*) and in a tunnel driven through the contact at the old turquoise workings north of the road the fault may be seen. At the turquoise workings the vertical plane between gravel and bedrock is particularly well displayed. Drill records obtained farther north along the trend of the fault support the same view. The downthrown side of the fault is on the south, as it is at both of the faults across the Mangas Valley.

It is difficult to trace this fault farther southwestward, for the rocks supposedly cut by it are all igneous, and there is little or nothing whereby to distinguish a fault from ordinary fracturing, much less to determine the direction or extent of movement. Nevertheless, there are certain features connected with the fracturing and metamorphism along this zone that support the idea that the effect of the fault persists for at least 2 miles farther to the southwest. These features consist, first, in a strong vein filled with fluorite a short distance north of shaft No. 2, showing brecciated material and slickensided walls; second, in an unusually abrupt boundary between rock which is thoroughly metamorphosed and fractured and rock in which there is decidedly less metamorphism; and third, in a line of benches flanking the northeastward-trending ridge in the southeast corner of sec. 21. These flanking benches may be clearly seen from any elevated point on the west side of Deadman Gulch opposite Copper Mountain. From an altitude of 6,300 feet on the east side of the creek the even tops of the ridges, transected by westward-flowing streams, become at once visible.

The topographic relations in this vicinity suggest a fault with the downthrow on the north, whereas the fault of which it has been presumed this is a continuation has its downthrow on the south. One of two explanations may be offered for this apparent anomaly. Either there has been rotation on the fault plane, about an axis located somewhere between the two points under consideration, so that at opposite ends of the block the fault is opposite in throw, or the present westward-facing scarp is due to superior hardness of the rocks on the south side of the fault (by reason of metamorphism), erosion thus being able to bring the north side to a lower elevation.

Whatever conclusion may be reached regarding this point, the physiographic evidence bearing on which is set forth at another place, it seems highly probable that this line represents the extension of the fault. Further support to this belief is afforded by the fact that to the southwest, in direct line with this supposed fault, there are a number of alined topographic saddles in which prospect holes show well-developed fault gouges. On the map, therefore, this fault is indicated by a dashed line passing through these saddles.

Other evidence of faulting within the district consists in brecciated veins within the mines and at the surface. A number of these veins are described in the section on the ore bodies.

As no evidence of overthrusting has been found in this region, all the breaks mentioned above are considered normal faults.

AGE OF FAULTING.

Movement along fault planes in this region has persisted down to a late date, as is proved by the intricate fault system cutting the lava ranges in the northern part of the Silver City quadrangle and in the Little Burro Mountains and by the fault planes along which Pleistocene gravel abuts against older formations.

To establish the precise date at which faulting began is more difficult. Beginning during Cretaceous time, it was probably connected with the folding that has affected the Cretaceous rocks and quite probably was brought about by igneous invasion.

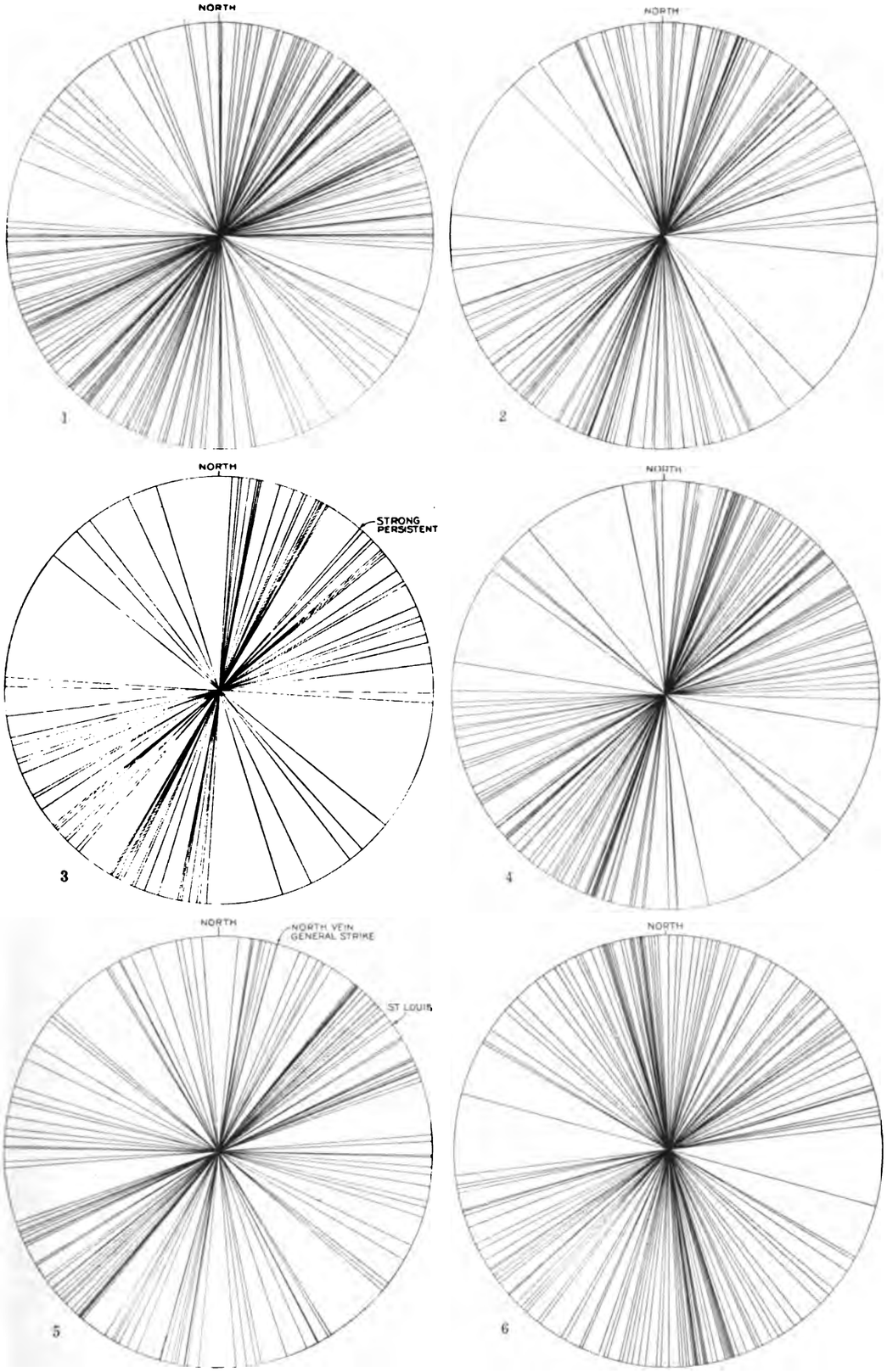
The strongest argument supporting the belief that the faulting began at an early date lies in the fact that the intense mineralization and alteration of the quartz monzonite porphyries is dependent upon intricate fracture systems connected with the faulting; and the mineralization surely took place soon after intrusion and probably during the cooling of the deeper portions of the magma. For this reason it becomes logical to assume the sequence of intrusion, folding, faulting (with fracturing), and mineralization in the Cretaceous history of the region.

FRACTURING.

DISTRIBUTION.

Fracturing of the rocks in the Tyrone district has been carried to great lengths. Associated with this fracturing has been intense metamorphism. The following statements concerning the distribution of fracturing therefore apply equally well to the distribution of metamorphism.

The principal fracture zone of the district is included within a roughly triangular area whose base may be considered the gravel and hard rock boundary between Tyrone and Oak Grove and whose apex is at a point about 2 miles southwest of Leopold. (See Pl. II, in pocket.)



DIAGRAMS ILLUSTRATING THE DIRECTION OF THE LARGER FRACTURES OF THE MINES IN THE TYRONE DISTRICT.

1, 400 level; 2, 200 level; 3, B sublevel; 4, 300 level; 5, A level; 6, Bison ore block.

The degree of fracturing throughout this area is not the same. It is more intense along the northwest side of the triangle and most intense between the towns of Leopold and Tyrone. Southeast of this zone of maximum intensity and extending nearly to the granite contact on the southeast the fracturing, though not so intense, is nevertheless very evident.

The change from very thoroughly fractured rock to rock that is much less broken is remarkably abrupt along the northwest side of this area, occurring in places within a quarter of a mile. This feature is particularly noticeable in the vicinity of Copper Mountain on Deadman Gulch and along the boundary to the southwest and northeast of that place. (See Pl. II.)

This zone is believed to mark a line of notable movement. Southwestward from Leopold, however, an appreciable diminution in the degree of fracture may be noted until at the point indicated on the map as the apex of the triangle intense fracturing is no longer present, though nowhere within the district are the rocks free from fractures.

On the southeast side of the fracture zone under discussion the change from fractured to relatively unfractured rock is more gradual and is marked by no pronounced structural feature. The curved line delineating the southern boundary of the zone in a measure expresses this condition.

The position of the major zone of fracturing is independent of rock type. Both granite and quartz monzonite porphyry have been fractured. The main contact of these rocks east of Leopold directly crosses the trend of the fracture zone.

Beyond the limits of the principal zone intense fracturing is confined to individual veins and shear zones. A shear zone extends southwestward for about a mile in secs. 10 and 15 and is coincident with the position of a small porphyry dike. The old workings of the rich turquoise deposits of the Azure Mining Co. are on this zone.

NATURE OF THE FRACTURING.

The fracturing of the rocks is directly connected with faulting. It may indeed be regarded as a distributive type of faulting, wherein the movement of relief instead of being limited to a few large breaks is taken up by a great number of minor breaks. It is believed that in the main where there existed a tendency to form large open fractures either the intrusion of a dike or the collapse of the rock closed such openings.

A striking feature of the individual fracture is its discontinuity. Extending for a few feet or for several hundred feet, it then grows weaker and dies out, its place being taken by another of similar character but having a more or less different strike, dip, and degree of prominence. The fractures are thus compound breaks, and even the strongest, those carrying evidence of considerable movement, partake of this character. Such, for example, is the North vein, the hanging wall and footwall of which for

FIGURE 5.—Diagram illustrating the nature of the systems of anastomosing fractures of which the mineralized fracture zones are made up.

several feet are essentially fracture or crushed zones. The St. Louis vein is another typical example of such fractured ground. (See mine descriptions below.)

The fracture planes are rarely plane surfaces, being characteristically uneven and warped and of irregular shape and extent. Although the direction of a particular zone of movement may be well defined, the individual fractures that together make up this zone follow this direction only approximately. Such an anastomosing system is illustrated in figure 5. This irregularity is shown vertically, as well as horizontally, on the vein and is characteristic of all the veins, from those that carry brecciated zones 8 or 10 feet in width to minute, hairlike breaks.

An analysis of the dominant trend of the fracture systems within the mines shows that these trends are not everywhere the same.

In Plate IV the azimuths of many fractures have been plotted about the center of a circle. On level A there is concentration in a N. 45°–60° E. direction, with a noticeable number trending N. 70°–80° E. and fewer N. 10°–15° E. In the northwest quadrant the directions are varied and the fractures are present in only minor amount.

On the tunnel level (not shown in Pl. IV) there is heavy concentration along lines N. 70° E. and N. 80°–85° E., with some concentration in a N. 10° W. direction, also N. 70° W.—in fact, the fractures trend in all quarters of the circle.

In the Bison ore block there is marked concentration in the northwest quadrant, particularly N. 5°–10° W. and N. 15° W. There is, however, an even distribution throughout from N. 60° W. to N. 80° E.

On the 200-foot level fractures are well disposed through the northeast quadrant but are concentrated around N. 20° E.

On the 300-foot level there is heavy concentration near N. 20° E. and N. 10° E., with some concentration at N. 60° E. Fractures are well distributed throughout the northeast quadrant, in fact, but are generally lacking in the northwest quadrant.

On the 400-foot level there is heavy concentration between N. 40° and 45° E. and between N. 60° and 65° E., with generally dispersed fracturing throughout the northeast quadrant. Scattering fractures are found in the northwest quadrant, and there is some concentration north and south.

On sublevel B there are concentrations at N. 4°–12° E., N. 25°–31° E., and N. 40°–50° E., with other fractures scattered in the northeast quadrant and also in the northwest quadrant.

By far the greater number of these fractures dip to the east, generally at rather high angles, though there are many exceptions to this generalization, both as to direction and angle of dip.

BRECCIA.

At two places within the Tyrone district there are brecciated zones of rather unusual character, in that the broken block of ground was not apparently dependent upon a simple fracture or set of fractures. One breccia occurs within the Burro Mountain Copper Co.'s mines and is known as the Breccia ore body; the other is on the summit of a small hill in the northeastern part of sec. 26.

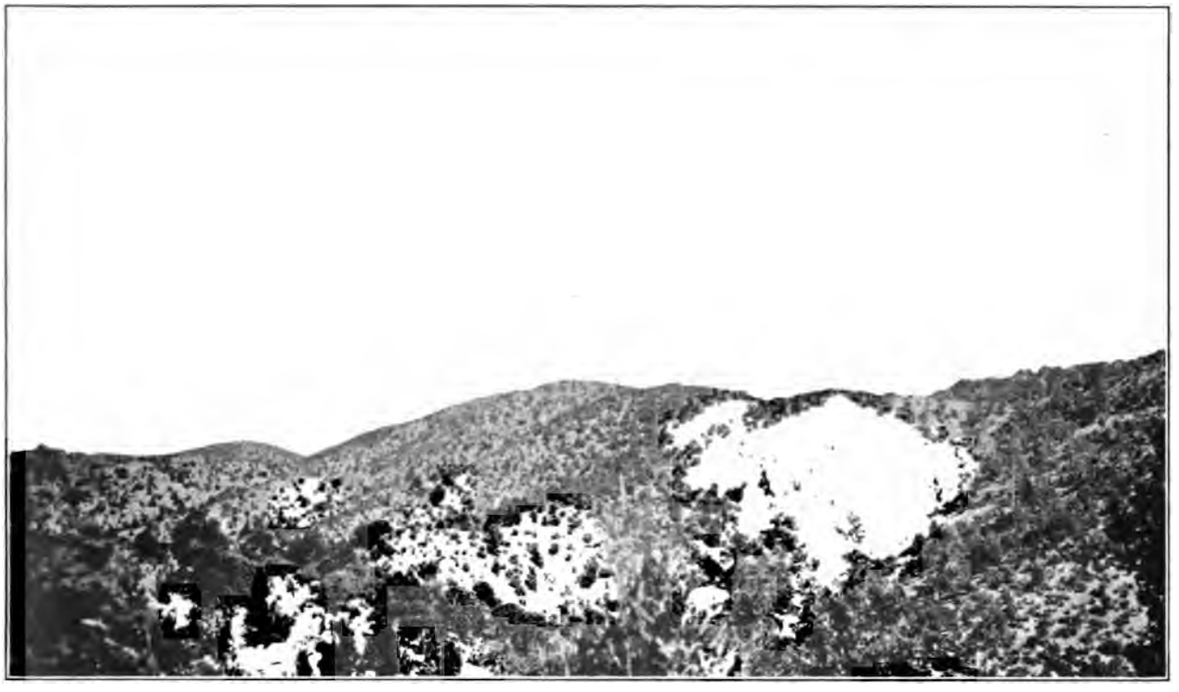
The irregular and ill-defined outline of the Breccia ore body is roughly indicated on the plans and cross sections. (See fig. 23, p. 44.) It is not the same on the various levels. On the 300 and 400 foot levels its dimensions (narrow and long) suggest association with ordinary fractures. How deep this breccia descends is not known to the writer. The mines were not unwatered below the 400-foot level at the time his investigation was being carried on.

The breccia is composed in large part of angular fragments of granite, and the matrix is generally of the same material, only more finely crushed. In places intrusive aplite dikes form a large portion of the breccia. As the pre-Cambrian granite is composed of granite of various types, it is not surprising that the breccia presents an appearance of great heterogeneity. In places crushed aplite makes up most of the breccia, and, as shown on the maps, porphyry intrusives partly border the breccia, particularly on sublevel B. The fragments vary in size, and the largest are several feet in diameter. Later fractures cut the breccia and pass from fragment to matrix.

It is not easy to determine positively the nature of the movement that caused this breccia. Certain of its features, however, suggest a reasonable explanation. First, the breccia is in the main composed of angular fragments of material not noticeably different from the matrix in which they are set. Some of the fragments are rounded. Second, the breccia is associated with intrusions of fine-grained porphyry—in fact, the fine-grained porphyry is in places brecciated. Third, the breccia has been fractured by movements since its formation. Fourth, there are no strong breaks parallel to the breccia which would make of it a fault breccia associated with a particular vein or set of veins.

The dynamic history of the region suggests only two processes which might have played a part in the formation of the breccia—faulting and intrusion. It is reasonable to suppose that both processes acted somewhat as follows:

The pre-Cambrian granite was subjected to tensional stresses accompanied or soon followed by both fracturing and intrusion. Rugged gaps were torn in such rocks as granite, and magma flowed in to fill these gaps. Movement did not cease then, however, but followed repeatedly, and the newly intrusive rocks were likewise torn apart. Some of this movement of distention (the result of uplift) was compensated by the formation of normal faults. In other places the magma filled the gaps formed by the movement. In yet other places,



A. COPPER MOUNTAIN, LOOKING NORTHEAST.

B. HILLSIDE OF SILICEOUS IRON-STAINED GOSSAN ABOVE THE SAMPSON ORE BODY.

of which the breccia block is considered one, the net result of the application of forces and the possibilities of relief was the collapse of extensive blocks of ground. Such a conception is reasonable when it is borne in mind that a wide area was being literally torn apart. If by circumstance a detached block of ground was not supported by the immediate introduction of magma, or by movement along appropriate shearing planes, further pressure might well accomplish its complete demolition, as in the case of the Breccia ore body. That such a place might be the site of subsequent movement is also reasonable, for such is the history of all fault movements in this and other districts. The actual entrance of the magma may have taken part in the brecciation by tearing blocks of rock asunder, for brecciation along dikes is not an unusual feature in the district.

The brecciation may be considered, then, a phenomenon directly connected with the violent dislocation that attended the distention of the country rock and its invasion by magma.

METAMORPHISM.

DISTRIBUTION AND GENERAL RELATIONS.

The rocks throughout the several fractured terranes described above have to varying degrees lost their normal igneous characteristics. Their original constituents—the feldspars, the quartz, and the ferromagnesian minerals (biotite and hornblende)—have been partly or wholly replaced by sericite, quartz, and pyrite, with lesser amounts of chlorite, biotite, and chalcopyrite; and superimposed upon this primary alteration have been changes caused by the downward circulation of oxidizing surface waters, wherein valuable concentrations of copper minerals have been brought about.

In consequence outcrops within the more intensely fractured areas are iron stained and siliceous and of various hues of yellow, brown, and red, and in places the courses of strong veins are marked by a typical "iron hat." (See Pl. V, *B*.)

The fracturing was the necessary forerunner of this alteration or metamorphism, for the rocks that are not fractured show no appreciable alteration, and the intensity of alteration is a direct function of the intensity of fracturing. This generalization applies equally well beyond the principal zone of alteration—for example, along individual shear zones. In this district the two conditions are interdependent; a zone of notable fracture is generally a zone of alteration. This view is supported by the fact that the degree of alteration is practically independent of the rock type affected. Granite, granodiorite porphyry, and allied dikes are altered to degrees depending not on their chemical constitution but on their degree of fracture. Thus, for example, the principal zone of alteration crosses the main contact between pre-Cambrian granite and granodiorite porphyry; and the rocks across the Mangas Valley, beyond the prominent northwest-southeast fault, though probably of later age than the porphyry west of Tyrone, show in part intense alteration—an alteration connected with a fracture system which, it seems to the writer, is independent of the main fracture zone of the district.

NATURE OF THE METAMORPHISM.

The metamorphism of the rocks of the Tyrone district was brought about by two very different and altogether unrelated sorts of chemical activity. One involved changes produced by ascending hot alkaline solutions arising, so far as can be determined, from deep-seated igneous rocks, supposedly the lower portions of the quartz monzonite porphyry, now exposed at the surface; the other includes only changes produced by descending cold, slightly acidified rain waters, principally active above the zone of permanent ground water. The ore deposits of the district are in a measure due to the activity of both of these processes, but they are particularly related to the second process, without which there would have been no enrichment of copper minerals.

These processes are discussed in detail under the heading "Mineralization" (pp. 24–40).

PHYSIOGRAPHY.

The geologic history of the Silver City region has been outlined on pages 7–10. The last chapter in this history, namely, the development of the present land forms, has special application to the ore deposits of the Tyrone district and therefore deserves more extended discussion.

The dominant topographic features comprise the Little Burro Mountains, a monoclinal fault block; the Big Burro Mountains, an erosion remnant standing well above the surrounding

country; the great gravel plain, for the most part an accumulation of rock waste in an extensive inclosed basin and having minor topographic features depending on erosion and aggradation; and a planated rock surface, now scored by erosion, bordering the Big Burro Mountains and merging on its outer border with the gravel plain. A minor feature is the panlike depression within the planated area, formed by the erosion of the unaltered quartz monzonite porphyry. All these features are primarily the result of the erosion of rocks of varying hardness under special topographic conditions in a semiarid climate, modified by faulting.

Inasmuch as the copper deposits of the district occur beneath the planated rock surface above referred to, it is obvious that the processes involved in its formation and those effecting the enrichment or other modification of the ore bodies are related. A somewhat extended analysis of the history and origin of this planated surface is therefore warranted. A consideration of land forms will also throw light on the faulting of the region and thus aid in deciphering the history of the ore deposits.

Many observers have commented on the fact that numerous mountain ranges in the southwestern part of the United States rise abruptly from sandy desert plains, like islands from the sea. The streams that flow down their canyoned sides pour out débris in a series of great fans, whose edges coalesce to form sloping plains. The process of aggradation is in full play. An inspection of the Pleistocene deposits in most of the Silver City area, however, indicates clearly that a decided change has taken place along their edges.

Although the deserts farther south are still areas of active aggradation, or building up, much of the corresponding part of this area is being actively eroded. Yet there is abundant evidence that these gravels once formed an unbroken sheet that lapped up on the mountains they surround. The observer who stands upon the Big Burro Mountains and looks northward over the valley of Mangas River can not fail to be impressed, even astonished, at the intricacy of the carving by which the even-topped sheet of sand and gravel is cut into innumerable gullies and canyons, nor can he fail to conclude that the gravel must once have extended farther toward the steep mountain scarps.

An interesting question immediately arises in connection with this intricate carving of the Pleistocene deposits: When and why did erosion become so manifestly active? The answer may be read in certain prominent physiographic features of the neighboring hard rocks. These features may be best observed from an elevated viewpoint. To the northwest from the summit of Four A Mountain may be seen a remarkably fine example of a rock bench, which slopes gradually from the foot of the lava range on the northeast to the edge of the gravel sheet on the southwest. This bench is about 2½ miles wide. It has three prominent characteristics—its inner border terminates abruptly against a steep mountain flank, it slopes evenly away from the mountains and is continued in the gravel without a break, and it is sharply incised by canyons that pass into the gravel.

Across the gravel toward the southwest there is a narrower but similar bench, which, when viewed from the top of the Little Burro Mountains, appears strikingly accentuated, forming the broad slope at the foot of the Big Burro Mountains. These benches may be explained by tracing to its end a cycle of erosion proceeding under the special conditions imposed by subaerial filling of inclosed basins of wide extent in an arid or semiarid climate.[13]

It is assumed, first, that inclosed basins were formed by a disturbance of level, such, for example, as that which produced the Basin Range system, with its partly buried mountains and detritus-filled inclosed valleys, continental warping probably being the underlying cause. Next is assumed a climate so arid that evaporation would prevent the rise of water in these basins and thus augment subaerial accumulation. These two conditions being assumed, it is apparent that a basin would be progressively filled from its center outward, and that this process of progressive burial would permit erosion to act with accumulating effect upon each succeeding unburied portion of the basin—that is, the last part to be covered would have undergone the greatest erosion. Although it is true that there would be appreciable deposition of coarse gravel near the borders of the basin where streams debouched from the mountain

[13] Paige, Sidney, Rock-cut surfaces in the desert ranges: Jour. Geology, vol. 20, pp. 442-450, 1912.

canyons, it should be borne in mind that such deposition must be confined largely to the stream ways. The interstream areas would remain without a mantle of gravel and thus continue to be subjected to erosion long after the center of the basin was effectively masked with fine débris. If the basin were of great extent the last part to suffer burial would probably have become a nearly planated surface. This end seems inevitable for the following reasons: First, the edge of the accumulating gravel sheet—below which (vertically) erosion could not extend—determines a local base-level, and, second, the territory above the gravel would constantly tend to become reduced to the level of the gravel. But this level is slowly rising; therefore the end product of such a cycle would be a sloping, evenly cut rock plain abutting against a mountain scarp.[13] The maintenance of this scarp is due partly to the cutting action of the mountain stream as it successively occupies the opposite borders of the convex alluvial fan formed at the canyon mouth. Such a plain formerly bordered the Big Burro Mountains, and the copper deposits of the district lie beneath its surface.

At present, however, this Big Burro Mountain bench is undergoing strong dissection, which, though probably a result of various causes, is believed to be due mainly to faulting and accompanying tilting of the faulted blocks. The gravel, in consequence, has been swept outward and removed from the surface of the bench, and relatively deep canyons have been cut in the underlying hard rock.

Evidence to prove that the mineralized area is a tilted, faulted, fractured block may be found, first, in the master fault along the west border of the Little Burro Mountains (with downthrow on the west), which limits the Tyrone block on the east; and second, in the fault entering the Tyrone district from the northeast and crossing St. Louis Canyon a short distance above the old town of Tyrone (a fault downthrown on the south at Tyrone, but probably upthrown on the south farther west, as indicated by certain benches to be mentioned later). Moreover, there is both direct and indirect evidence that the gravel sheet formerly extended much farther westward.

The last two points need elaboration. In the section on faulting the evidence is set forth to support the statement that the fault which enters the Tyrone district from the northeast is downthrown on the south at Tyrone. Farther west, however, it has not been possible to locate this fault except by indirect evidence. Thus, it is known that the hypothetical extension of the fault would correspond to the northern boundary of the main fracture zone; but this boundary occurs wholly within igneous rock, and the needed direct criteria for proving its presence are lacking. At this point the aid of physiography (the interpretation of land forms) becomes valuable. Just west of Copper Mountain and east of Deadman Gulch there are certain benches cut in rock and located precisely where the hypothetical boundary of the fault passes and at the border of the main fracture zone. These benches, however, indicate a fault upthrown on the south, for their surface is presumed to correspond with the higher planated surface to the southeast, across the supposed fault. This throw is therefore opposite to that of the fault at Tyrone. The question is naturally raised, Is there not a hinge point somewhere between these benches and Tyrone? Such a hinge point would in part account for the failure to trace the fault, for movement would be slight in the region of the hinge.

The conclusions that these benches indicate a fault, and that this fault is upthrown on the south are further supported by the following facts: This line of disturbance may be traced a mile still farther southwestward, as shown on the geologic map, and coincides with the position of several alined topographic divides in which prospect drifts show well-defined fault gouges. Faulting is thus clearly indicated.

Again, the maximum elevation of these benches, 6,280 feet, corresponds with the top of the planated surface to the north, across the intervening valley; whereas immediately to the southeast, across the assumed fault, the top

[13] Lawson, A. C., The epigene profiles of the desert: California Univ. Dept. Geology Bull., vol. 9, pp. 23-48, 1915.

of the surface is at 6,400 feet, indicating a throw of 120 feet, with the uplift on the south.

Returning to the evidence presented by the position of the edge of the gravel sheet, in support of the idea that tilting has occurred, we may refer first to the fact that on the southern border of the Big Burro Mountains the gravel extends within a short distance of the steep slopes of the mountains. This is conceived to be the normal position of the gravel at the end of the cycle of erosion discussed above. Further, in some places in the Silver City region isolated outliers of gravel indicate that the main boundary has been eroded basinward; and finally, there are deposits of iron-cemented gravel in the vicinity of Tyrone whose mode of origin indicates that their present position at the edge of the gravel sheet has been established recently (in geologic time); formerly such deposits were deeply buried, and the border of the gravel sheet was farther mountainward.

Thus, in the light of all the evidence available, it would seem reasonable to postulate that the planated rock surface beneath which the copper deposits occur was first a smooth gravel-covered, sloping plain; that it was subsequently faulted and tilted eastward; that the gravel was stripped from its surface and canyons cut within it; and finally, that during all these changes the copper deposits were being more or less modified.

PART II.—THE COPPER DEPOSITS.

HISTORICAL NOTES.

Until the late seventies and early eighties the Burro Mountains were the stronghold of the savage Apaches, and it was a common belief that no prospector ever returned who chanced to wander into the region. The beautiful Mangas Valley, to the northeast, received its name from the notorious Apache chieftain Mangas Coloradas (Spanish for red sleeves), whose deeds are written in blood on the pages of frontier history. It is probable that the Indians mined for turquoise before the district was known to white men.[14]

The "old timer" John E. Coleman, better known in the early days as "Turquoise John," is generally credited as being the discoverer of the district, as no prospecting of any consequence was ever done before his time. He was in the district in 1879 and made a number of locations of both copper and turquoise, having discovered turquoise in some ancient workings during that year. Nevertheless it seems that Robert and John Metcalf were the first to make locations in the region, about 1871. They found both turquoise and copper.

The St. Louis deposit was discovered in 1879 by James Bullard, John Swisshelm, and J. W. Fleming, and shipments of surface ore were made to Denver.[15] The discoverers negotiated a sale with Paschal R. Smith and Frank Marshall, who organized the Val Verde Copper Co. and erected a 50-ton reverberatory furnace in Deadman Gulch. The town around the works was called Paschal. The company owned the St. Louis, Burro Chief, Boston, Marshall, Copper Mountain, and several other claims. The nearest railroad point was Deming, N. Mex., over 50 miles distant, and the wagon haul cost $50 a ton. The ore was obtained mostly from the St. Louis mine and smelted in the reverberatory furnace. The supply of high-grade material was small, and the operating costs were so high that the company soon failed. Later a 500-foot shaft was sunk on the St. Louis claim, and a large body of sulphide ore was found.

Two years later another company, under the management of Colonel Smith, built a smelting plant at Oak Grove, but this ran only a short time.

Soon afterward Judge Deming organized the Alessandro Copper Co. to work a group of claims about 3 miles east of the St. Louis mine. The treatment plant installed here involved a leaching process, using sulphuric acid made on the ground from pyrite. The low grade of the ore, the lack of a railroad, and the attempt to leach 30 years ago resulted in failure.

The Val Verde Copper Co. merged with the Southwestern Copper Co., and all operations were suspended on account of marauding Indians. During this time other discoveries were made in the district, among which was the Sampson deposit, found by George Sublett and Robert Thompson.

In 1904 Theodore Carter interested the Leopold Brothers, of Chicago, in the St. Louis mine and other properties and organized the Burro Mountain Copper Co.[16] This company took over the St. Louis, Sampson, Boston, and other claims belonging to the Southwestern Copper Co. A 150 to 300 ton mill was built at Leopold and treated 4 per cent ore from the Sampson and St. Louis claims.

In 1904 Phelps, Dodge & Co. bought a third interest in the company and acquired at the same time an option on the remaining two-thirds of the property.

About 1905 the Comanche Mining & Smelting Co. and the Copper Gulf Development Co. started developing property in the camp. They merged later as the Savannah Copper Co.

In May, 1906, the Briggs Oliver Development Co. took under option the Burro Chief group, belonging to Thomas S. Parker, and started Nos. 1, 2, and 3 shafts at Tyrone. This company later became the Tyrone Development Co., and then the Chemung Copper Co. It carried on extensive development work,

[14] Jones, F. A., New Mexico mines and minerals, pp. 55-56, 1904.
[15] Bush, F. V., Min. Press, February 6, 1915, p. 222.
[16] Wade, R. W., Eng. and Min. Jour., Aug. 15, 1914, p. 287.

sinking shafts, driving drifts, crosscutting, and blocking out ore bodies.

The Phelps Dodge Co. bought out the Leopold interests in the Burro Mountain Copper Co. and in 1913 purchased the Chemung Copper Co. and the property of a number of individual claim holders.

NATURE OF THE DEPOSITS.

The principal copper deposits of the Tyrone district are chalcocite ore bodies in porphyry and granite. They owe their value to the enrichment of pyrite and chalcopyrite by descending rain water. No primary ore is mined in the district. The deposits exhibit all the characteristics of the now well-recognized chalcocite "porphyry" ore. The chalcocite is either disseminated regularly throughout large masses of fractured country rock or concentrated along exceptionally strong veins or shear zones. The valuable ore bodies are characterized by both these features. The chalcocite ores are everywhere overlain by ground of variable thickness either barren of copper minerals or containing carbonates and other oxidized copper minerals, and at varying depths beneath the workable chalcocite ores the primary pyrite is everywhere encountered. The deposits are clearly related to zones of intense fracturing and do not appear where such fracturing is lacking. As they exist to-day, they are not the result alone of a long period of enrichment but clearly reveal the effects of perhaps equally extensive impoverishment.

The principal ore bodies lie within a northeastward-trending zone of fracture between Leopold and Tyrone. They may be considered the end result of, first, primary mineralization of a fracture zone in porphyry and granite; second, enrichment by downward percolating rain water at various stages in their development; third, impoverishment of previously existing ore at various stages by leaching.

In harmony with the nature of their origin, the ore bodies are very irregular in size and shape. They range from roughly blanket-like masses, grading upward into oxidized ground and downward into primary pyrite, to strong veins or shear zones, which are likewise barren near the surface and too lean to be of value below, where chalcocite gives way to primary pyrite.

The East ore body, about 700 feet long and 600 feet in greatest width and related to two strong fractures, is typical of the blanket type. At the top and bottom the body has little horizontal extent, but it swells notably at the middle, its form being regulated somewhat sharply on the west and northwest by the St. Louis and North veins, respectively. To the east and south the ore merges with country rock carrying too little copper to be regarded as ore.

The so-called "flat veins" of the Chemung group are typical of the shear-zone type. Here strong central anastomosing veins constitute, with the adjoining wall rock, profitable ore bodies.

The roughly cigar-shaped form of the richer bodies near Leopold may be discerned from the mine maps, where the narrowing and widening of the worked-out stopes on various levels may be clearly seen.

It is highly probable that the localization of all these ore bodies was determined by the presence of an appreciably greater amount of chalcopyrite than is found on the average throughout the rock mass.

PRIMARY MINERALIZATION.

GENERAL FEATURES.

The primary mineralization of the granodiorite porphyry and the granite was effected by the passage through these rocks in numberless channels, some large but most very small, of great quantities of aqueous solutions, the mineral content of which not only filled the countless open fractures in the rock but metasomatically replaced the wall rock of fissures great and small, searched out the innermost parts of the rock mass, and, to various degrees of perfection, performed its work of alteration. Although the changes thus accomplished, measured by the quantity of material introduced, indicate a chemical interchange on a vast scale, the minerals formed are few in number and characteristic throughout the area.

Of the nonmetallic minerals, sericite and quartz far exceed in amount any others. Indeed, except for a little chlorite, a little secondary biotite, a little calcite and epidote, and an amount of fluorite not easily estimated (as described below), they may be said to be the

characteristic nonmetallic accompaniment of the alteration.

Of the metallic minerals, pyrite is preeminently the most abundant, and considering the fact that copper is the valuable metal sought in these deposits, there is an astonishing scarcity of chalcopyrite and a lack, so far as was observed, of any other primary copper mineral. A little zinc sulphide occurs, also a little molybdenite, but besides these there is a dearth of introduced metals. Sericite and secondary quartz are present in the metamorphic rocks in amounts ranging from a few scattered flakes of sericite within the feldspars to aggregates almost completely replacing the rock. Of these two minerals, however, sericite is by far the more abundant.

FORMATION OF SERICITE.

The formation of sericite has apparently proceeded under two sets of physical conditions—it has filled open cracks in the rocks as veinlets, either with or without quartz, or it has metasomatically replaced the constituents of the rock. The second mode of occurrence is the predominant one. The nature,

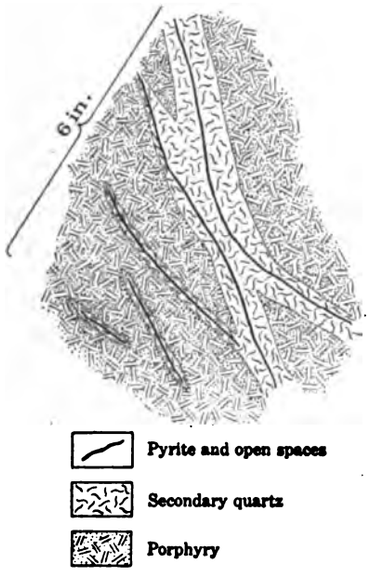


FIGURE 6.—Metasomatic replacement of porphyry by pyrite veinlets, sericite, and quartz.

texture, and composition of the rock replaced, the nature of the solution that accomplished the alteration, and the time during which it acted each affected the end results. Slightly altered granites may show a few flakes of sericite scattered through the feldspars. In another place the chemical composition of parts of zoned feldspar may have offered the necessary chemical environment, and the sericite is seen in an orderly arrangement within the

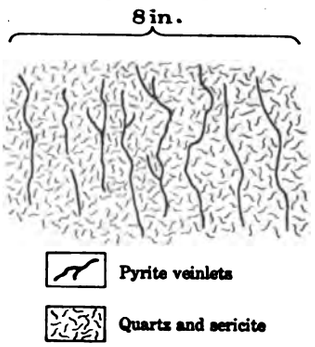


FIGURE 7.—Pyrite, sericite, and quartz replacing porphyry in a sheeted zone. In places this process affects large blocks of ground.

feldspar, following crystallographic directions or cleavage planes. In rocks more strongly affected the feldspars may all be filled to various degrees with sericite blades, while the quartz remains entirely unaltered. In a yet more advanced stage sericite replaces the edges of quartz grains, and from this stage on a progressively more nearly complete replacement may be observed to those rocks in which quartz and feldspar alike are filled with sericite blades.

How quartz is formed or introduced in these various stages is not clearly understood. The fact that it fills cracks in the other mineral grains as countless veinlets and larger veins is clearly observed, but quartz has also replaced the walls of veins and veinlets, and in such positions it is not everywhere clear what portion has been introduced and what portion is a residuum from reactions involving the formation of sericite. (See fig. 6.) From a study of thin sections, however, and from observation in the field, it is believed that the bulk of the secondary quartz occurs either in open fillings or in the replaced walls of the veins not far from the feeding channel of circulation. It may thus replace a large body of rock in a sheeted zone where ready access was afforded to the circulating solutions. (See fig. 7.)

It may be shown that the deposition of quartz and that of sericite are under certain assumed conditions intimately related—that

the formation of the sericite demands the setting free of a certain amount of silica. Whether this silica is immediately redeposited or not would depend upon conditions, the arbitrary assumption of which leads to no particularly valuable conclusion. For example, the replacement of a molecule of albite by a molecule of sericite, if the silica of the albite molecule remains constant—that is, furnishes all the silica needed—results in a volume change, which demands more space for the resulting sericite than was taken up by the albite molecule. Of necessity, then, silica of the albite molecule was set free to be deposited immediately near by as quartz or to be carried off in solution. Observation of many thin sections shows that in some places the quartz was clearly not deposited near by and therefore was carried off in solution. Where the rock certainly contains more quartz than originally the question may well arise, How much of this quartz is residual and how much introduced? But the original rock was so variable in its content of quartz as to make an answer to this question of little value.

On the other hand, if the anorthite molecule is replaced by sericite, stable silica being assumed, there is insufficient quartz in the anorthite to fill out the entire space with sericite, and therefore silica must be supplied by the solution.

If all the material of the albite molecule were replaced by the sericite molecule—that is, if all its silica took part in the reaction—a larger space would be needed, and thus it is evident that this reaction can not take place if such space is lacking. Probably, therefore, a portion of the albite molecule goes into solution before replacement properly begins, and it is this general rule that must operate wherever it can be shown that replacement does not proceed by interchange of equivalent weights.

As a matter of fact the igneous rocks involved in these reactions contain feldspars which are mixtures of the albite and anorthite molecules.

If the porosity of the altered rock may be used as a criterion of the resultant, it would seem that ample space was at hand for these reactions, for the pore space of the altered rock exceeds that of the unaltered rock.

The transformation of feldspar to sericite, theoretically at least, may be brought about by highly heated water alone, thus: Orthoclase reacting with water alters to sericite, potassium silicate, and silica.

$$3KAlSi_3O_8 + H_2O = KH_2Al_3Si_3O_{12} + K_2SiO_3 + 5SiO_2$$

The potassium silicate is carried off, while the liberated silica may be partly removed in solution or it may recrystallize as quartz.[17] Or the reaction may be chemically expressed as follows,[18] water containing carbon dioxide being the only reagent necessary:

$$3KAlSi_3O_8 + H_2O + CO_2 = KH_2Al_3(SiO_4)_3 + K_2CO_3 + 6SiO_2$$

Sericite forms with as much ease from oligoclase, andesine, and labradorite as from orthoclase,[19] as is supported by field evidence at Tyrone, where all these varieties of feldspar are more or less transformed to sericite.

The occurrence of notable amounts of fluorite as a vein filling at several places in the Tyrone district and observations in the mines, below the zone of chalcocite enrichment, which suggested that quartz phenocrysts in the porphyry had been dissolved raised the question whether fluorine had not been active in secondary alteration and whether its source was to be sought not only in fluorite but also in sericite. It is well known from analyses that muscovite carries fluorine, but its presence in sericite has not been supported by so much evidence. Spurr [20] has argued that fluorine is necessary for the formation of sericite, but his tests were not convincing as to the fluorine content of sericite, though its presence to the amount of 0.12 per cent in a specimen (which contained no sericite) indicated that the waters which altered the rock contained it.

Believing that the influence of fluorine may be very potent in both the primary and the secondary alteration of the rocks, the writer selected a typical sericite vein for analysis, and the presence of fluorine in the sericite was definitely established.

The specimen chosen for analysis was part of a replacement vein about 1 inch thick, typical

[17] Clarke, F. W., The data of geochemistry, 4th ed.: U. S. Geol. Survey Bull. 695, pp. 596–597, 1920.

[18] Lindgren, Waldemar, Metasomatic processes in fissure veins: Am. Inst. Min. Eng. Trans., vol. 30, p. 608, 1901.

[19] Bischof, G., Lehrbuch der chemischen und physikalischen Geologie, 2d ed., vol. 1, pp. 31 et seq., p. 44, 1863.

[20] Spurr, J. E., Geology of the Tonopah mining district, Nev.: U. S. Geol. Survey Prof. Paper 42, pp. 232–233, 1905.

of countless similar veins that traverse the fractured altered rocks. Its mineralogy was simple, as it consisted of quartz, sericite, and pyrite. After the specimen was freed from as much pyrite as possible the following results were obtained on analysis:

Analysis of specimen from replacement vein.

[George Steiger, analyst.]

Silica (SiO_2)	68.11
Alumina (Al_2O_3)	16.84
Ferric oxide (Fe_2O_3)	.80
Ferrous oxide (FeO)	3.53
Lime (CaO)	.44
Magnesia (MgO)	.50
Soda (Na_2O)	.44
Potash (K_2O)	4.08
Sulphur (S_2)	3.15
Fluorine (F)	.09
	97.98

The mineral composition computed from this analysis is quartz 45.30 per cent, sericite 46.09 per cent, pyrite 6.68 per cent, and by allotting all the fluorine to the sericite it may be shown that this mineral carries practically 0.20 per cent of fluorine, a notable amount.

Thus as the sericite generally contains an appreciable amount of fluorine, the explanation of the breaking down of feldspar by hot waters alone or by carbonated waters may be considered simply as a supporting argument for a far more potent cause—that is, the presence of fluorine in the primary solutions.[21]

PYRITIZATION AND THE INTRODUCTION OF COPPER.

The silicification and sericitization of the rocks was accompanied in many places by pyritization and the introduction of copper, probably in the form of finely disseminated chalcopyrite. The pyrite accompanies quartz in numberless veinlets and veins (see fig. 8) and also impregnates the wall rock. In fact, there is every reason to believe that the sulphur needed to form the pyrite was an element in the solutions which carried the potash necessary for the formation of sericite. The outline of pyrite grains within the wall rock of veins is usually sharp, transecting quartz, feldspar, and sericite alike, suggesting that the mineral was formed during a late stage of the metamorphism. It is true that in some places sericite blades may be observed penetrating grains of pyrite, but this is unusual and indeed would seem to point to no more than contemporaneity of origin at that place. There is no evidence to be gathered from the thin sections to support the view that the pyritization was decidedly earlier than the sericitization and that the sericitization was a late phenomenon, as is held by Rogers,[22] who concludes that "Sericite is a rather low-temperature mineral formed at or toward the close of the hydrothermal period."

The pyrite varies greatly in amount. It is most abundant in strong veins where circulation has been very active. At certain places within the Breccia ore body pyrite is exceptionally abundant, solidly filling spaces several feet in diameter, between fragments of the breccia.

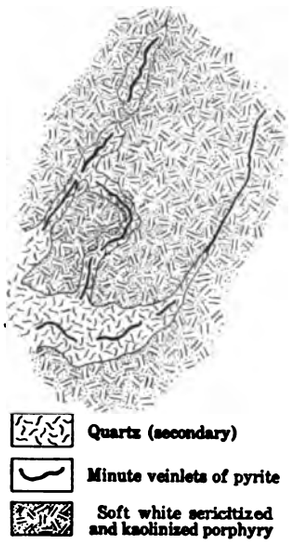


FIGURE 8.—Minute veinlets of pyrite accompanied by quartz cutting sericitized porphyry.

COMPOSITION OF THE SOLUTIONS.

If, as shown above, the primary alteration of the rocks consisted in the formation of sericite, quartz, and pyrite, accompanied by fluorite, epidote, calcite, and chlorite, it may pertinently be asked, What was the nature of the solutions that performed the work? No analyses of the rocks in this district have been made. This course was decided upon after careful consideration of results in other places where

[21] Paige, Sidney, and Steiger, George, Fluorine in sericitization: Washington Acad. Sci. Jour., vol. 8, pp. 234-239, 1918.

[22] Rogers, A. F., Econ. Geology, vol. 11, p. 145, 1916.

almost precisely similar associations or rocks and metamorphic processes prevail. It has been shown that in such districts potash has been introduced while soda, lime, magnesia, and alumina were removed; also that sulphur has been introduced while the proportion of quartz apparently remained about stationary.

It is believed that in the Tyrone district fracturing was the forerunner of metamorphism and that the degree of the one influenced the degree of the other; and as the intensely fractured zones contain great quantities of visible vein quartz and afford evidence that the walls of numberless veins were replaced by quartz it does not seem possible to believe that the silica present in the original rock at any particular level was sufficient to account for the quartz which may be observed. The same conclusion is believed to be warranted as regards the iron in combination with sulphur to form pyrite. Although the iron of the ferromagnesian minerals, biotite and hornblende, did combine with sulphur to form pyrite, as is clearly indicated where these minerals are altering to chlorite, sericite, pyrite, and quartz, yet the large quantities of iron necessary to form the pyrite of the heavy veins must, in part at least, have come from below.

If for a moment the more obvious nature of the reactions involved is considered, some idea of the elements in solution may be obtained. If, for example, potash was being exchanged for soda, lime, and magnesia, then all these elements must have been present in the solution, for at no particular point could it be determined that any of them was depleted. That some of the iron or alumina or soda may have been picked up below and that some potash may have been lost below can not be denied. In fact, that the solution was constantly varying in character as the reaction went on seems a necessary conclusion. Thus conceived, it would seem that sodium, potassium, magnesium, iron, sulphur, copper, zinc, silica, and fluorine were all present. That under the conditions that prevailed the solution was nearer concentration by potash than by any other of these elements would seem axiomatic from the sericitization of the rocks. It is also apparent that progressive enrichment of sodium and lime would take place in the solution.

ORIGIN OF THE SOLUTIONS.

The type of alteration just described implies the movement through the rocks of great quantities of aqueous solutions. It is futile to attempt an absolute proof of the origin of these solutions from deep-seated igneous rocks, but that they did so originate is for many reasons the most probable hypothesis. Alteration of this type is characteristic of fractured zones near and within intrusive bodies chemically allied to the one at Tyrone throughout a wide territory in the western United States and other parts of the continent. It has been shown that fracturing probably soon followed intrusion. Igneous dikes cutting the main mass indicate waning igneous activity. That aqueous solutions should continue to be given off from lower portions of a fractured consolidated magma is reasonable, and there is nothing in the nature of the elements which these solutions have been shown to contain that opposes this view. Indeed, the presence of fluorite and less conspicuously of apatite in veins indicates a magmatic source of the solutions. The intensity of the alteration indicates hot or at least warm waters. It is true that surface water might sink and later become heated, but there is nothing to show that this occurred here. Any hypothesis which assigns such alteration and mineralization to meteoric circulation must explain when and how the various substances needed were taken up and should cite evidence that such water at great depths exists and facts to prove that it could circulate through appropriate channels.

The association of springs with volcanic activity, the admitted and proved content of water in igneous magmas, and the connection between igneous magmas and volcanic activity all point to the conclusion that such solutions as are here considered were probably the last expression of a period of magmatic injection.

ALTERATION.

GENERAL CONDITIONS.

For a long time, perhaps during more than one period of erosion, rain water has been falling upon the surface of the altered rocks of the Tyrone district. These rocks when first exposed to erosion were composed essentially of feldspar, quartz, sericite, and pyrite, with a

small percentage of chalcopyrite. They are now very different. That part of the rain water which sank beneath the surface has produced important changes.

At the surface in the place of pyrite there are at the present time limonite and hematite in great abundance, kaolin, and in sparing amounts the oxidized copper minerals, malachite, azurite, chrysocolla, cuprite, etc. Native copper occurs in a few places. Lower down there is pyrite coated with chalcocite or wholly replaced by it; in places this is the predominant mineral. Still deeper it becomes less conspicuous, and the unaltered pyrite is the only sulphide visibly present.

The factors that control the speed and thoroughness with which such a change takes place are physical. The depth to which oxidation can be effective is governed, first, by the fractures in the rock; second, by the position of the ground-water table, below which oxidation does not occur to an important degree. The thoroughness of the process is dependent upon the ease of circulation and the quantity of water supplied. Under stable conditions, which are seldom if ever realized, all the copper would ultimately be deposited as chalcocite near the water table. Thus viewed, the block of ground between the surface and the water table has acted in a measure as a great selective filter through which rain water leaching out the copper from higher levels has precipitated it again within narrower limits below. The process, however, is a chemical one.

Several factors have served to complicate the orderly oxidation of the mineralized rocks. First, the topography and underground drainage in this region have not always been as they are to-day. In consequence, the position of ground water has shifted from time to time. Second, the degree of fracturing varies greatly in different parts of the rock body, and circulation has therefore been irregularly distributed.

GROUND WATER.

The records of a number of drill holes prove that at the present time ground water thoroughly saturates the rocks below a rather definite level. This nearly plane surface slopes gently from the country west of Tyrone to the Mangas Valley, beneath which it is nearly horizontal. It slopes gently northward down the Mangas Valley and southward toward the desert and Deming. The cross sections in figures 9 and 10 clearly bring out these facts. Sections approximately north and south along the Mangas Valley show that the water level beneath the gravel does not vary more than 60 feet in elevation, whereas the elevation of the surface may vary several hundred feet. This is to be expected. The gravel that fills the Mangas Valley is porous, and water falling there easily finds its level. The gentle upward slope of the water table toward the west corresponds almost exactly with the slope of the rock surface that borders the gravel deposits and reaches the Big Burro Mountains. Such an accordance of slope and the fact that at other points the level of water corresponds proves that the rock here also is saturated below a rather definite level. Its porosity, however, is due to fracturing.

The position of this water table does not apparently bear any significant relation to the position of maximum enrichment of the chalcocite ores. (See cross sections, figs. 9 and 10.) At some places enrichment ceases above the water table; at others the position of maximum enrichment corresponds with the water table; at still others it descends well below the water table. This variation suggests that when the ores were formed the position of the water table was quite different from that of to-day. Moreover, there are places in the mines where barren sheeted zones carrying limonite and quartz cut through and below bodies of chalcocite ore. Such evidence supports the idea that the conditions that govern enrichment to-day are radically different from those that prevailed when the chalcocite ores were being formed at the levels where they are now found. This discordant relation of ore to ground water is further emphasized by a consideration of the chalcocite in relation to primary pyrite. The depth to which chalcocitization has been effective varies greatly, and the bottoms of the ore bodies are very irregular surfaces.

PERIODS OF ENRICHMENT AND CHANGES IN THE LEVEL OF GROUND WATER.

An explanation for the conditions described above must be sought in the geologic history of the region. Fortunately the broad studies of the Silver City quadrangle afford some basis for such an explanation.

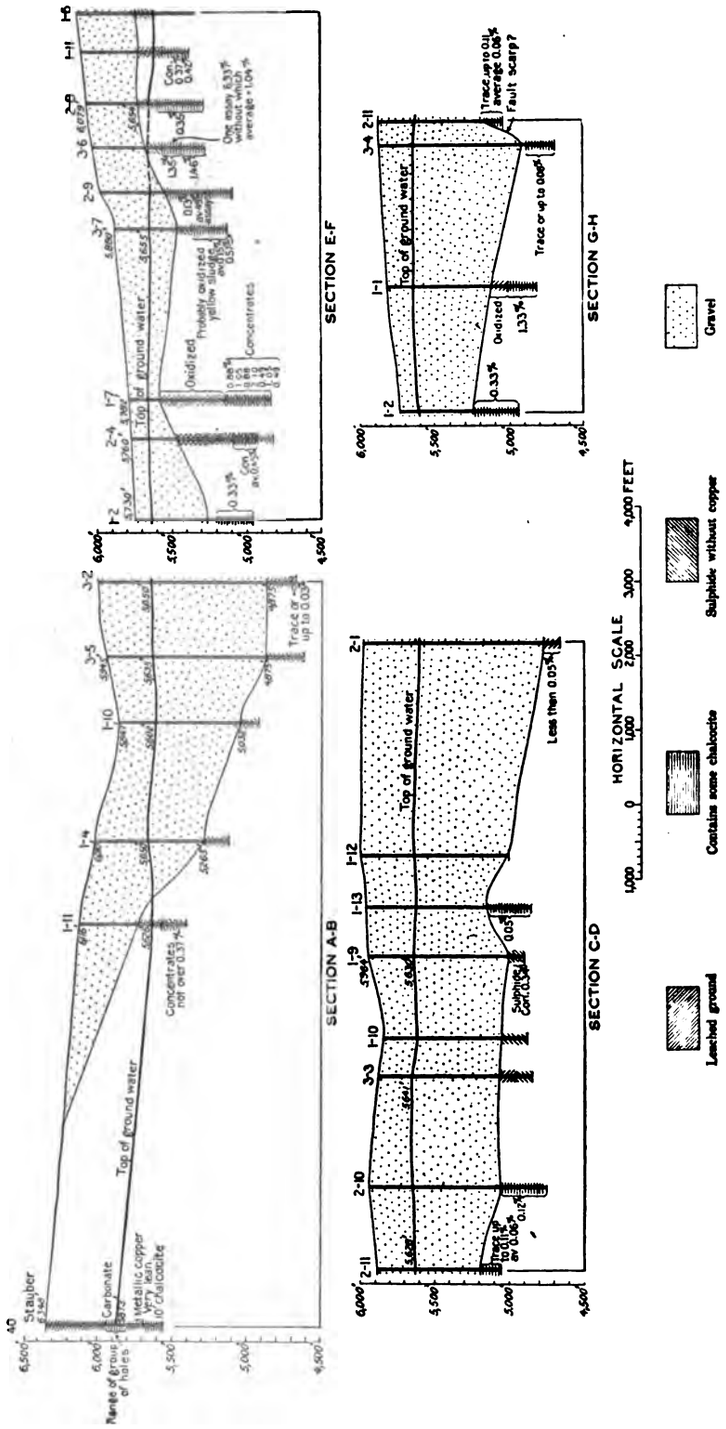


FIGURE 9.—Cross section showing relation of ground water to chalcocite enrichment.

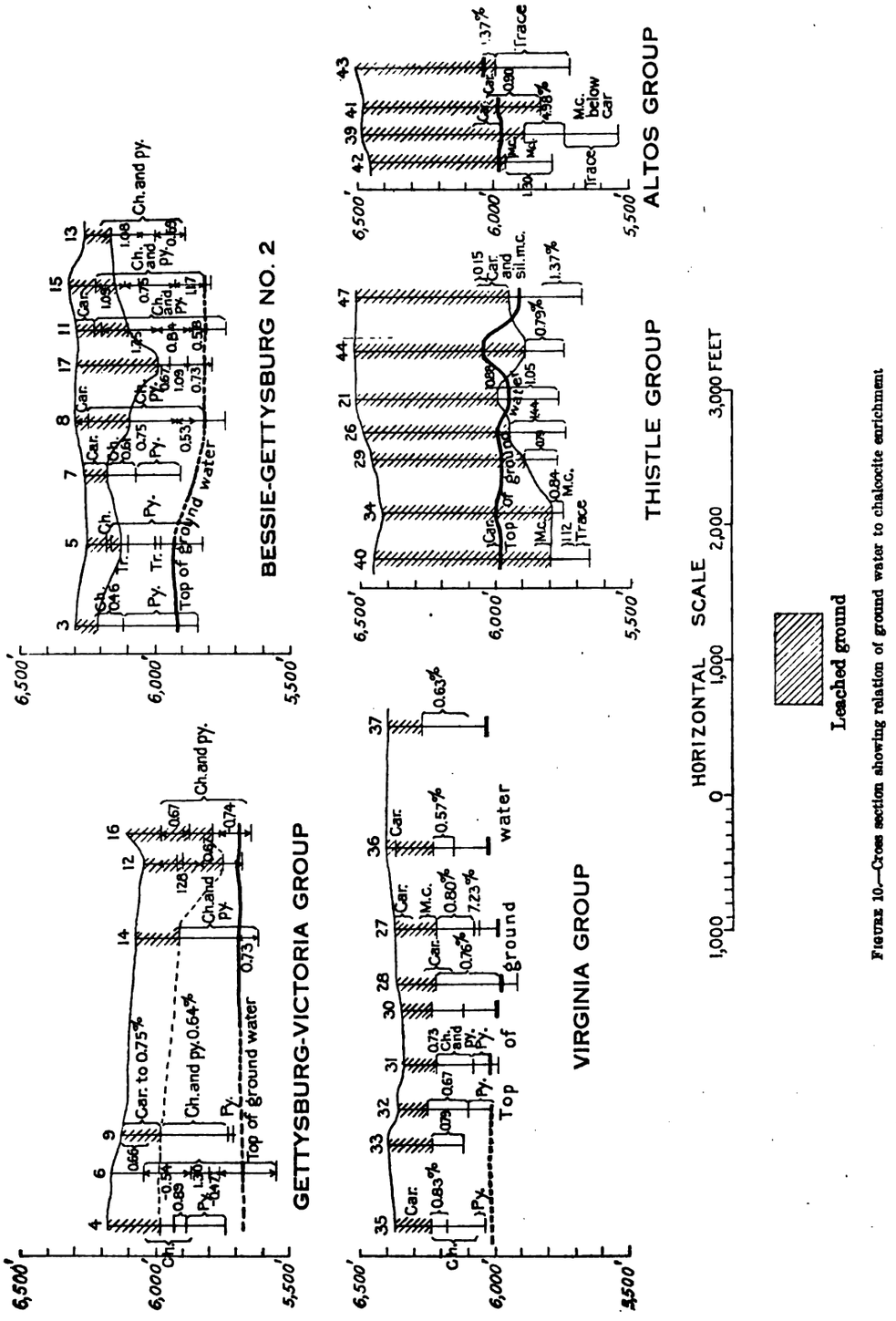


FIGURE 10.—Cross section showing relation of ground water to chalcocite enrichment

Evidence is clear that Tertiary lavas flooded a country of irregular relief, already eroded to sufficient depth to expose the mineralized quartz monzonite at Tyrone. At that time, however, the outcrops of the monzonite stood higher than at present and formed no such even plain as is indicated by the topography of to-day. Enrichment began, therefore, well before the lavas appeared.

The position of the ground water at that time can only be conjectured, but it is reasonable to suppose that the water table was more irregular than at present, for the topography was more rugged. This supposition is also supported by evidence furnished by drill records in the Tyrone district, for the bottom of the enriched ore is extremely irregular and clearly was not determined by any particular level of ground water—that is, the chemical activity of the descending solution that formed the ore was not halted by the presence of any regular sheet of underground water. Evidently the chalcocite never came into contact with such water. The maximum depth at which it was deposited was determined by other factors than the presence of a water table.

How far enrichment proceeded before lava flooded the country is not known, but such flooding must have very effectually retarded the processes of enrichment. This pre-lava enrichment may be considered the first stage in the development of the ore bodies. Then followed a long period during which the rocks were again being stripped from above the mineralized area. During this second period of erosion conditions of the underground water were surely different from those that prevailed during the first period, and probably during this stage of the formation of the ores the leaching so evident in the mines occurred. It is conceived that the new conditions of erosion and underground drainage set up by this lava flooding and the crustal adjustments that probably took place incidentally thereto may account for this leaching, which is so difficult to explain otherwise than by referring it to some period wherein the physiographic control of drainage was radically different from that of the present. These leached zones, within which steeply dipping sheets of ground containing essentially only limonite and quartz descend far below present water levels, pass through the ore bodies and well into regions of unoxidized pyrite. This period of post-lava leaching may be considered the second stage; it probably passed by insensible gradation into the third stage.

An essential initial condition of this third stage must have been the outlining of great structural undrained basins as a result of warping and faulting. There is evidence that this condition was reached slowly. For example, the drainage of the Little Burro Mountains points clearly to a gradual rise of these mountains. The streams cut directly across the mountains. As the block rose the streams were able to cut their channels down equally fast. It may well be that the raising of this block impounded the ground water and caused it to rise in the Tyrone area.

Then began the great accumulations of gravel now so widely distributed, occupying these great inclosed basins. The underground drainage, formerly so free, now underwent a gradual change. Extensive planated surfaces sloping gently to the edge of the gravel deposits from the mountains were formed. These surfaces were cut in rock. Their formation, as has been pointed out in the chapter on physiography (pp. 19–22), was directly brought about by the accumulating gravel deposits. These surfaces are in the nature of peneplains, with the difference that during their formation the level toward which erosion tended to lower them was gradually rising. The portion of these plains farthest removed from the gravel deposit was the portion more perfectly planated.

It is evident that while such plains were being cut along the borders of the gravel deposits the ground water beneath the gravel rose gradually as the gravel filling proceeded and extended beneath hard rocks where these were fractured, up the slopes of the planated rock surface, as it does to-day. It is equally evident that as soon as ground water reached a particular level in the mineralized pyrite zone enrichment ceased below that level. The areas covered first by the gravel, therefore, were the first in which enrichment became inactive. The area farthest away from the gravel sheet remained subject to enrichment the longest. With this relation in mind, it is a striking fact that the richest ores of the Tyrone district are to the west, at the maximum distance from the gravel sheet, also that they are the shallowest. Their richness may

well be due to their relatively prolonged period of enrichment; their shallowness may well be due to the higher stand of the ground water, for the ground water slopes upward toward the mountains on the borders of inclosed desert basins, and probably here it always stood higher than toward the valley.

Physiographic evidence elsewhere within the Silver City quadrangle shows that deposits of gravel extended well up the slopes of such planated rock surfaces as are being considered here, and it is reasonable to suppose that ground water at such times stood higher than it does to-day—that is, the chalcocite zone at Tyrone was probably once flooded even more than it is at present. Direct evidence on this point consists in iron-cemented gravels lying upon the porphyries. These indurated deposits are precise markers of horizons where the top of ground water passed from solid rock into gravel. (See fig. 11.) They occur where water, passing into porous gravels from the more solid rock, deposits a portion of its iron content as limonite. Such deposits in the Tyrone district therefore prove not only that the gravel extended farther west than at present (these deposits are now at the edge of the gravel), but that the ground water once stood much higher, for it is now far below these deposits. This high stand of ground water may be considered the culmination of the third stage of enrichment.

The fourth stage in the development of the ores was initiated by the movements that upset conditions producing aggradation and brought about the dissection both of the gravels and of the planated rock surfaces, the marked effects of which are so prominent in the topography to-day. During this stage faulting was probably very active, and the particular block of ground here considered is believed to have been tilted to the east, having been broken along the fault that borders the west side of the Little Burro Mountains. Such tilting would have the effect of raising the chalcocite zone on the west side of the block with reference to ground water, while relatively lowering it on the east side. Here again, therefore, enrichment was more favored to the west than to the east.

This period of erosion, however, while in all probability it served to enrich portions of the ore bodies—for example, those under hills—resulted in a second period of impoverishment of other portions, such as the leached ground in valleys, consequent on the erosion which they have suffered. Thus the fourth stage in the development of the ore bodies is brought up to the present time, when leaching and enrichment are both going on above the ground-water table. Should conditions remain stable for a long period, a concentration of chalcocite will be brought about near water level.

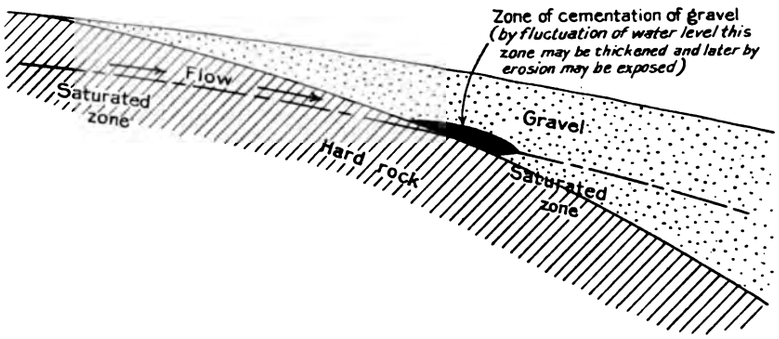


FIGURE 11.—Relation of iron-cemented gravel to ground-water level. Fluctuations in the level of ground water may thicken the cemented portions, and erosion with accompanying lowering of ground water may expose such accumulations at the surface, as found in the Tyrone district to-day.

FORMATION OF CHALCOCITE.

The study of the chalcocite ore bodies at Tyrone leaves little room for doubt that they were produced by enrichment. Although the lower portions of many ore bodies could not be examined, being under water, it is believed that no facts of particular importance would have been discovered had these portions been accessible, for there was an opportunity to observe both the top and the bottom of several chalcocite ore bodies, and there is no reason to believe that others were essentially different.

The primary sulphides are pyrite and a very small amount of chalcopyrite. The chalcocite replaces to various degrees both of these minerals. (See fig. 12.) Usually above an ore body there is a zone of leached ground in which sulphides are lacking. Still higher there may be carbonates and oxides, near or at the surface. In other places the chalcocite zone is surmounted immediately by oxides and carbonates, no barren zones being present.

At various depths the chalcocite zone merges with the zone of unaltered pyrite, and here there are in places prominent veins of kaolin-like products metasomatically replacing the pyritized porphyry.

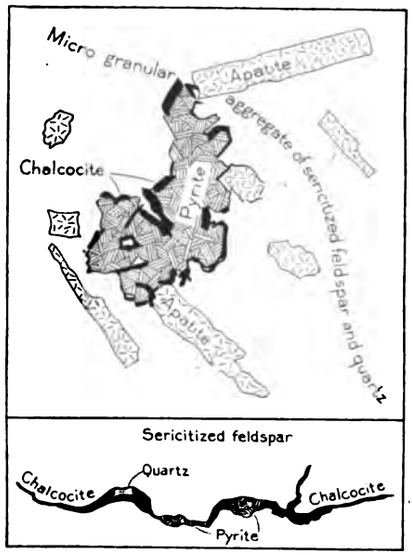


FIGURE 12.—Pyrite coated with chalcocite embedded on and in veins in sericitized porphyry.

The explanation of enrichment is found in the chemical interaction of rain water and the primary sulphides contained in the porphyry. According to Spencer,[23]

Rain water carries in solution the various gases of the air, including oxygen and carbon dioxide. In arid and semiarid regions it contains also noteworthy amounts of common salt, which may be regarded as of wind-blown origin. As these waters pass into the soil and into the porous weathered capping that lies above the ore mass they come into contact with orthoclase and mica and with oxidic compounds of iron and copper and basic carbonates of copper. (Note here that the process being described is that in progress at the present time and does not begin with the unoxidized pyrite. The result is, however, essentially the same, as will be pointed out below.—A. C. S.)

Metallic copper and the red oxide cuprite are also fairly common in the overburden. The silicate minerals in the capping tend to make the water alkaline,[24] but as they are only slightly attacked, this tendency is likewise slight. Of the metallic minerals in the capping, those containing sulphate decompose, being somewhat soluble, the final result being to produce and to leave in place insoluble limonite and copper carbonates and to furnish small amounts of iron and potash sulphates to the solution. Thus far the dissolved oxygen does not enter largely into reaction, because most of the minerals of the capping are already fully oxidized. The only exceptions to be noted are cuprite and native copper. Also, the carbonic dioxide has been by no means exhausted. Beneath the capping the solution encounters material rich in sulphide minerals that are subject to ready oxidation. Here, then, chemical action between the oxygenated water and the sulphide minerals ensues, a series of reactions being initiated, of which series the culminating reactions involve the deposition of chalcocite. At first the water contains free sulphuric acid furnished by the decomposition of pyrite, but gradually the acid becomes neutralized by bases furnished by the gangue minerals, and at sufficient depths the solutions become alkaline.

In the Tyrone mines, however, prominent veins of kaolin below the zone of chalcocite enrichment indicate the presence of free sulphuric acid. As the formation of chalcocite is accompanied by the formation of sulphuric acid, this condition would seem normal. Spencer continues:

If considered with respect to the minerals decomposed the reactions that occur beneath the capping present a succession of oxidations, whereas if considered with respect to the active solution the changes are of course as consistently in the direction of reduction. The reactions may be considered in three groups, assignable in a general way to higher, intermediate, and lower positions in the body of sulphide-containing material. In the upper part of a sulphide ore body atmospheric oxygen is the oxidizing agent; somewhat lower down, where free oxygen has been exhausted, ferric sulphate becomes active; and after the oxygen made available by this carrier has been utilized cupric sulphate furnishes oxygen. The *action of cupric sulphate*[25] on pyrite and chalcopyrite results in the deposition of chalcocite and the consequent enrichment of the material carrying the primary sulphides.

No attempt will be made here to review numerous experiments in chalcocite deposition undertaken during the last decade or earlier. This has already been done by W. H. Emmons.[26]

[23] Spencer, A. C., Chalcotite enrichment: Econ. Geology, vol. 8, pp. 622-624, 1913.

[24] Cameron, F. K., and Bell, J. M., U. S. Dept. Agr. Bur. Soils Bull. 30, pp. 12 et seq., 1905. Clarke, F. W., The data of geochemistry, 4th ed.: U. S. Geol. Survey Bull. 695, pp. 473-478, 1920.

[25] Italics by the writer.—S. P.

[26] The enrichment of sulphide ores: U. S. Geol. Survey Bull. 529, 1913; The enrichment of ore deposits: U. S. Geol. Survey Bull. 625, 1917.

The results of investigation have progressively tended toward harmonious conclusions. The progress of the theory of chemistry has been rapid during this same period. Electrochemistry, knowledge of the nature of colloids, and the application of physical chemistry to problems of ore deposits have all advanced rapidly. The summary which follows will present only those formulas which seem to offer an explanation of the changes involved. Stated for the first time in an orderly arrangement by A. C. Spencer in 1913 (though in part naturally based on the work of his predecessors), these formulas have been supported in part recently by the fundamental work of the Geophysical Laboratory at Washington.[27] Spencer inquires "whether the oxygen dissolved in rain water could alone have effected the oxidation of the mass of material which has contributed the secondary copper now contained in any given ore body." He answers this query in the negative, presents data to support his contention,[28] and concludes that "a large part of the oxygen must have been derived from air that circulated through the oxidized capping" and that "the greater part of the oxidation must take place during such times as the sulphides are merely moist rather than when they are flooded, because then the water could receive oxygen from the air in contact with it, at the same rate at which oxygen is being taken out of solution by the reaction of oxidation."

That part of Spencer's analysis of the process that has direct application at Tyrone is quoted below.[29] His analysis falls into three parts—first, the changes wrought by free oxygen; second, those produced by ferric sulphate, where free oxygen is no longer available; third, the oxidation by cupric sulphate, the last oxidizing agent. To this sequence of chemical reactions may be added the final stage of secondary rock alteration, the kaolinization of the primary ore material by sulphuric acid, active below the chalcocite zone.

OXIDATION BY FREE OXYGEN.

Beneath the capping the sulphides first encountered by waters that carry dissolved oxygen are pyrite and chalcopyrite. Just at the top of any porphyry ore body grains of these minerals persist after the removal of chalcocite coatings which they carried at a time when the bottom of the capping was slightly higher than at present. Here, too, is to be found some pyrite which never carried more than the slightest coating of chalcocite.

The sulphides named are of course readily decomposed by the oxygen-bearing solution. * * * The complete oxidation of pyrite may be considered as taking place in some such manner as represented in the derived equation (1).[30]

$$FeS_2+15O+H_2O=Fe_2(SO_4)_3+H_2SO_4 \ldots\ldots\ldots (1)$$

For chalcopyrite, (2) is an equation essentially analogous to (1):

$$2CuFeS_2+16O+H_2SO_4=Fe(SO_4)_3+CuSO_4+H_2O \ldots (2)$$

Part of the ferric sulphate formed at the upper surface of the body where free oxygen is present decomposes to form basic iron sulphates and hydrated iron oxide; another part may be supposed to pass downward in solution and to attack pyrite, chalcopyrite, and chalcocite. The formation of iron hydroxide may be represented in various ways—for example, as follows:

$$6FeSO_4+3O+3H_2O=2Fe_2(SO_4)_3+2Fe(OH)_3$$

The equations which have been given indicate that the decomposition of pyrite yields sulphuric acid and ferric sulphate. Under natural conditions solutions carrying these substances come into contact with chalcocite only a short distance below the point where pyrite and chalcopyrite were first encountered. Here, if any free oxygen remains, chalcocite is decomposed, with the formation of cupric sulphate:

$$Cu_2S+H_2SO_4+5O=2CuSO_4+H_2O \ldots\ldots\ldots (3)$$

The reaction indicated by this equation may be considered as using up the last of the free oxygen which can reach a body of enriched porphyry ore under ordinary conditions. At points immediately below those where the free oxygen has been entirely consumed, ferric sulphate and cupric sulphate are present. Both these compounds are capable of oxidizing the sulphides, but the former is more readily reduced than the latter, and it may be supposed to undergo almost complete reduction to ferrous sulphate before the latter can come into play as an oxidizing agent.

OXIDATION BY FERRIC SULPHATE.

* * * According to Vogt[31] the action of ferric sulphate on chalcocite, which would come into play below the shell of nearly complete oxidation, is as follows:

$$Cu_2S+2Fe_2(SO_4)_3=4FeSO_4+2CuSO_4+S \ldots\ldots (4)$$

[27] Zies, E. G., Allen, E. T., and Merwin, H. E., Some reactions involved in secondary copper sulphide enrichment: Econ. Geology, vol. 11, pp. 407-503, 1916.

[28] Spencer, A. C., op. cit., p. 631.

[29] Spencer, A. C., op. cit., pp. 632 et seq.

[30] Compare Stokes, H. N., On pyrite and marcasite: U. S. Geol. Survey Bull. 186, pp. 15, 19, 1901; Lindgren, Waldemar, Copper deposits of the Clifton-Morenci district, Ariz.: U. S. Geol. Survey Prof. Paper 43, p. 79, 1905 (this author gives an extended bibliography relating to pyrite oxidation); Allen, E. T., Sulphides of iron and their genesis: Min. and Sci. Press, vol. 103, pp. 413-414, 1911; Gottschalk, V. H., and Buehler, H. A., Oxidation of sulphides: Econ. Geology, vol. 7, p. 16, 1912; Tolman, C. F., Secondary sulphide enrichment of ores: Min. and Sci. Press, vol. 42, p. 40, 1913.

[31] Vogt, J. H. L., Problems in the geology of ore deposits: Am. Inst. Min. Eng. Trans., vol. 31, p. 166, 1902.

But if the sulphur set free reacts with more ferric sulphate SO_2 might be formed, and with still more ferric sulphate sulphuric acid will result, and eventually we may arrive at the equation suggested by Weed: [32]

$$Cu_2S+4H_2O+5Fe_2(SO_4)_3=10\,FeSO_4+4H_2SO_4+2CuSO_4 \quad (5)$$

* * * * *

The same reagent, ferric sulphate, may be considered as acting on pyrite in a manner represented more or less adequately by equation (6):

$$FeS_2+7Fe_2(SO_4)_3+8H_2O=15FeSO_4+8H_2SO_4 \quad (6)$$

It is to be noted that equation (6) is comparable with equation (1). For chalcopyrite an expression similar to (6) is:

$$CuFeS_2+8Fe_2(SO_4)_3+8H_2O=17FeSO_4+8H_2SO_4+CuSO_4 \quad (6a)$$

* * * * *

The foregoing discussion should make clear the following points:

First, that waters from the surface penetrating a body of porphyry ore will continue to decompose strongly the metallic sulphides present so long as they contain or can acquire free oxygen, or so long as they contain ferric sulphate. Second, that where chalcocite, pyrite, and chalcopyrite are all present the chalcocite will be largely and perhaps fully decomposed before the other minerals were attacked. Third, that the decomposition of chalcocite, pyrite, and chalcopyrite effects the reduction of ferric salts contained in the solution. Fourth, that the decomposition of pyrite, chalcopyrite, and chalcocite each tends to produce sulphuric acid. Fifth, that the decomposition of chalcocite and of chalcopyrite furnishes cupric sulphate to the solution. Briefly, then, when oxygen-bearing waters reach the upper part of the mass of sulphide-bearing rock the consumption of the dissolved oxygen begins at once, and before the waters can progress downward for any considerable distance all of this free oxygen is used up in decomposing the sulphides. Also within a short distance ferric sulphate is largely reduced to ferrous sulphate. So long as free oxygen is present the decomposition of chalcocite will progress until no sulphuric acid remains uncombined. It should be added that cuprous and ferric ions are always present in small concentration [33] in any solution containing cupric and ferrous sulphates.

OXIDATION BY CUPRIC SULPHATE.

The progress of the surface-derived waters has been followed to the point where they contain no free oxygen and only a minor amount of ferric sulphate but where they carry ferrous sulphate, cupric sulphate, and sulphuric acid. Thus far on its downward journey it may be assumed that the cupric sulphate has been protected from reduction because at ordinary temperatures and in acid solution it is less readily reduced than ferric sulphate.[34]

Beyond the place where the ferric sulphate concentration in the solution has been reduced to a certain minimum, cupric sulphate comes into play as an oxidizing agent. * * * Cupric sulphate attacks chalcopyrite and pyrite at ordinary temperatures, so that iron passes into solution as ferrous sulphate, sulphuric acid is formed, and a copper sulphide is deposited. The last part of this statement is supported by the fact that covellite and chalcocite are common products in nature where copper sulphate solutions from the upper zone of oxidation have encountered pyrite and chalcopyrite. * * *

The Stokes equation for chalcocite formed by replacement of pyrite through the action of cupric sulphate may be built up empirically. * * * Thus:

$$2FeS_2+2CuSO_4=Cu_2S+2FeSO_4+3S \quad [35]$$

$$3S+2CuSO_4=Cu_2S+4SO_2 \quad [36]$$

$$6H_2O+5SO_2+2CuSO_4=Cu_2S+6H_2SO_4$$

$$12H_2O+5FeS_2+14CuSO_4+8Cu_2S+5FeSO_4+12H_2SO_4 \quad [37]$$

In a similar manner the following equation indicating the replacement of pyrite by covellite may be deduced:

$$4H_2O+4FeS_2+7CuSO_4=7CuS+4FeSO_4+4H_2SO_4.$$

As thus derived each of the Stokes equations appears to summarize a succession of oxidation effects.

The replacement of pyrite by chalcocite has been recently made the subject of painstaking quantitative chemical analysis by Zies, Allen, and Merwin.[38] Their results agree perfectly with the formulas given above representing the changes pyrite to chalcocite and covellite to chalcocite.

Spencer notes that "the supposed change covellite to chalcocite under the action of cupric sulphate has not been established by experiment in which essentially pure natural covellite was used." Nevertheless, by an analysis of critical formulas [39] he evolves the equation

$$5CuS+3CuSO_4+4H_2O=4Cu_2S+4H_2SO_4$$

remarking that the establishment of this equation would be of noteworthy importance in the theory of chalcocite deposition. Since that time Zies, Allen, and Merwin [40] have estab-

[32] Weed, W. H., Enrichment of gold and silver veins: Am. Inst. Min. Eng. Trans., vol. 30, p. 429, 1901.

[33] Stokes, H. N., Experiments on the solution, transportation, and deposition of copper, silver, and gold: Econ. Geology, vol. 1, pp. 644-650, 1906. Wells, R. C., Discussion of secondary enrichment: Econ. Geology vol. 5, pp. 481-482, 1910.

[34] Stokes, H. N., Econ. Geology, vol. 1, p. 646, 1906.

[35] Vogt, J. H. L., Problems in the geology of ore deposits: Am. Inst. Min. Eng. Trans., vol. 31, p. 166, 1902.

[36] As intermediate between this equation and the one foregoing, the following reaction should be considered: $4H_2O+6CuSO_4+S=3Cu_2SO_4+4H_2SO_4$. (See Stokes, H. N., op. cit., p. 44.)

[37] Stokes, H. N., op. cit., p. 22.

[38] Zies, E. G., Allen, E. T., and Merwin, H. E., Some reactions involved in secondary copper sulphide enrichment; Econ. Geology, vol. II, pp. 407-503, 1916.

[39] Spencer, A. C., op. cit., pp. 640-641.

[40] Zies, E. G., Allen, E. T., and Merwin, H. E., op. cit., p. 425.

lished this equation by refined chemical synthesis and analysis.

KAOLINIZATION.

Kaolin or halloysite is common in the mines at Tyrone. This alteration product occurs along strong fractures and fault fissures, in

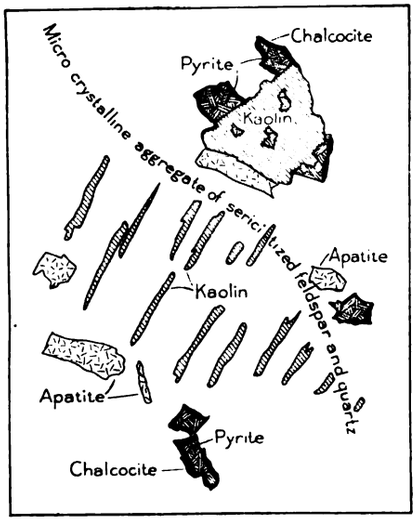


FIGURE 13.—Association of kaolin with chalcocitization of pyrite.

brecciated zones, and in anastomosing fractures in the porphyry and granite. It is found near the surface and in the deepest parts of the mines, beneath the zone of chalcocite enrichment. (See fig. 13.)

The form of the veins in which the kaolin is found at once suggests that this mineral is produced by the decomposition or metasomatic replacement of the porphyry and granite by descending acidified waters, and a further consideration of the nature of this chemical change suggests very strongly that fluorine, derived from the decomposition of sericite and fluorite, played a part in the transformation.

In places in the Breccia ore body vein systems of kaolin are without doubt formed by metasomatic replacement along what originally were minute fractures. The relations of the veinlets to the fragments of the breccia preclude the idea that movement has occurred along the walls of the veins. The fragments are not disturbed by the fractures. Moreover, the downward pointing of the smaller veins clearly indicates the direction of the movement of the waters that decomposed the porphyry. (See fig. 14.)

One feature connected with the formation of these kaolin veins deserves special consideration. It is the observed fact that quartz, even where present as noteworthy phenocrysts in porphyry or granite, yields ultimately, as well as the feldspar, to complete decomposition. At one place this change was observed with unusual clearness. Here a vein of kaolin between two small fractures merges at one end into porphyry, while in the opposite direction the kaolin-like product of decomposition is increasingly pure. Although the quartz was the last mineral to yield to decomposition, there was a considerable portion of the vein in which quartz was no longer present. (See fig. 15.)

In seeking to explain what was here clearly shown and what all the pure kaolin veins indicated, namely, that quartz suffered complete decomposition in the formation of kaolin, the possible agency of fluorine was invoked. As stated on page 26, the presence of fluorine in the sericite of the altered rock was proved;

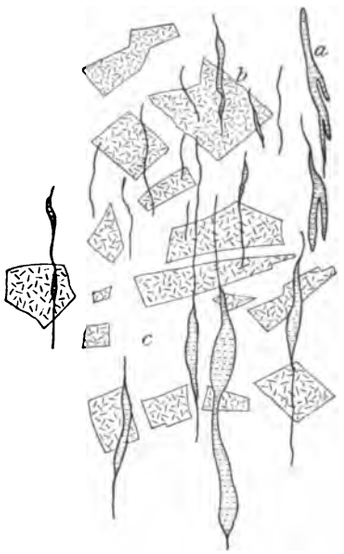


FIGURE 14.—Replacement of brecciated granite and porphyry (*b*) by kaolin veins (*a*). The relations indicate simple replacement without open fissure filling. *c*, Matrix of breccia.

and the mineral fluorite occurs in veins in the district and probably was generally present in minute veinlets in the altered porphyry.

Thus a vein known as the "fluorite vein" occurs about 160 feet north of the old No. 1 shaft of the Chemung Copper Co. The fluorite is several feet in thickness and may be traced 100 feet or more. Just above the Thompson shaft in Big Murry Gulch there is a vein carrying 6 or 8 inches of fluorite. These two occurrences indicate that fluorite may well have been abundantly deposited as a primary vein mineral, for though it was not noted in other places, this apparent scarcity is due to the reactions which theoretically should occur between fluorite and the descending acid waters of the zone of oxidation: fluorite would be removed. Fluorite is decomposed by sulphuric acid, with the formation of calcium sulphate ($CaSO_4$) and hydrogen fluoride (HF), and hydrogen fluoride unites readily with silica to form water and silicon tetrafluoride (SiF_4), a gas soluble in water. Silica would thus be attacked and carried off. It is known that

$$SiF_4 + 4H_2O = Si(OH)_4 + (4HF)$$
$$(4HF) + 2SiF_4 = 2H_2SiF_6$$
$$3SiF_4 + 4H_2O = Si(OH)_4 + 2H_2SiF_6$$

Thus silicon hydroxide and hydrofluosilicic acid are formed. The latter compound is stable only in water and is inert so far as attacking quartz is concerned. In the rocks under discussion here it would probably form alkaline salts. On evaporation of the water, however, silicon tetrafluoride (SiF_4) would again be formed and the more or less insoluble alkaline salts would be deposited. Whether the silicon tetrafluoride (SiF_4) set free would on recombining with water again produce the active agent hydrogen fluoride (HF) is not known. More probably the process outlined above would be repeated, a certain portion of silicon hydroxide ($Si(OH)_4$) being deposited and the inert hydrofluosilicic acid (H_2SiF_6) going again into solution, to combine again with alkaline bases.

Now, the alteration of sericite to kaolin has been observed and recorded by many investigators. Nevertheless, sericite is a very stable mineral, probably quite as stable as the alkaline salts formed by the evaporation of hydrofluosilicic acid. But it is to be expected that these salts will yield to decomposition by acidified waters, like sericite, and there is reason to believe that fluorine will be again and again set free, so long as sulphuric acid waters are operating.

Thus the mass of sericitized porphyry, originally perhaps containing veinlets of fluorite, yields fluorine from two sources—from sericite and from fluorite—and this potent agent no doubt was active in the formation of kaolin. Considered from this angle, the heavy "gouges" of kaolin-like material developed along large fractures are probably due in part to this process, for they were main channels of circulation, where the accumulated effects of fluorine concentration would be accentuated.

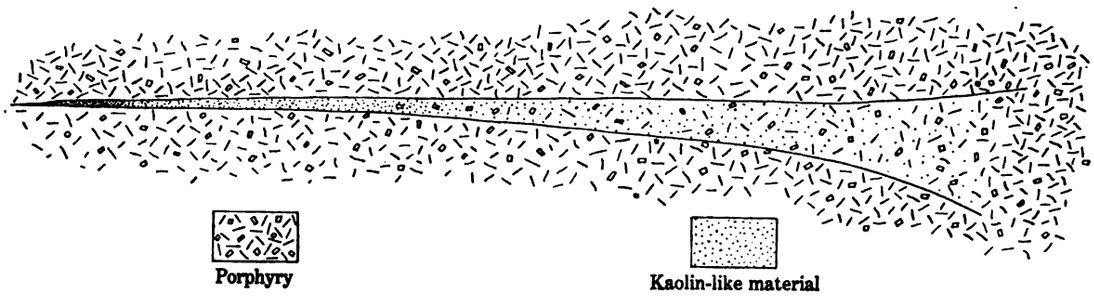


FIGURE 15.—Transition from porphyry to kaolin-like material in replacement vein of kaolin. Quartz phenocrysts survive the process of replacement the longest.

That sulphate waters played a part in this formation of kaolin is rather clearly indicated in a specimen of halloysite from the main tunnel (Burro Mountain Copper Co.), about 700 feet from the portal. Under the microscope this smooth, waxy green material reveals an isotropic mineral with an index of refraction of 1.527 (that of halloysite), and within this material in certain areas are myriads of tiny hexagonal crystals, each containing at its center a minute yellow grain. The crystals as a whole have positive elongation and are optically negative. Their index is about 1.59. These facts suggest that they are one of the jarosite series (sulphates of potassium and iron).

LEACHING.

The process of enrichment where ground-water level was stationary would theoretically result in the accumulation of all copper in a relatively thin chalcocite zone adjacent to ground-water level, extending from a position above this level to a certain distance below it.

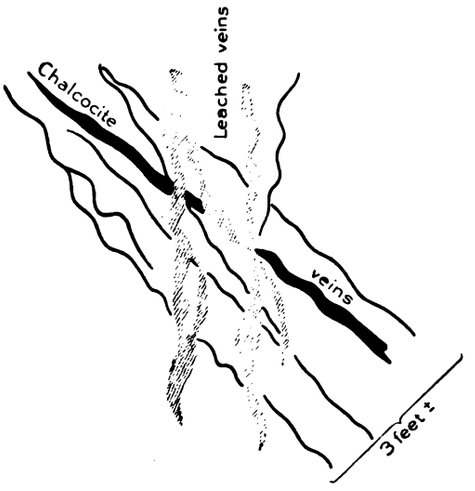


FIGURE 16.—Leaching of eastward-dipping chalcocite veins along later vertical veins carrying limonite.

Theoretical conditions, however, seem to be seldom if ever realized, and changes of water level upset the orderly deposition of chalcocite. Such has been the case at Tyrone, and as a consequence, in certain places, where formerly enriched sulphides were present there exist to-day only thoroughly oxidized bodies of rock impregnated and veined with iron oxide. (See fig. 16.)

The copper leached from these zones might under favorable conditions be recoverable below, but the facts at Tyrone do not justify hopes of such a recovery. As has been pointed out, there probably existed in the past a stage when ground-water level stood far below its present position, and it was presumably during this stage that considerable amounts of copper were removed from bodies of rock in which it had previously accumulated as chalcocite. The level of ground water was so deep during this stage of leaching that instead of concentration at definite levels there is reason to believe that copper may have been dispersed.

At the present time, when the water table is occupying a very definite level, it is difficult to escape the conviction that all copper that is being leached above the ground-water level is being redeposited somewhere above or just below this level; but there is no evidence in the mines that sufficient time has elapsed to permit any notable concentration at this present level of ground water.

In developing the mines, therefore, in search of new ore bodies, it becomes of first importance to discover criteria whereby the presence of bodies of chalcocite may be predicted, or at least whereby zones in which chalcocite is likely to occur may be distinguished from zones which are almost certainly barren.

Is there a difference to be noted in the leaching of chalcocite as contrasted with that of pyrite? Though it is not certain that such a distinction may always be made, the writer observed at several places in the Tyrone mines that, at least in the early stages, leached ground in which, there was every reason to believe, chalcocite had once been present was red, as contrasted with brown where only pyrite had been present.

In figure 17 the conditions in drift 48 on the fourth level (Burro Mountain Copper Co.) are illustrated. The drift is opened in pyritized porphyry, everywhere somewhat enriched by the deposition of chalcocite. Where leaching has taken place it has left a red stain. The encroachment of the leached zones upon the chalcocite zone is guided, as nearly everywhere, by prominent fractures. The area of strong red color at this particular place is preceded by an area colored to a lesser degree. Assays of the red material indicated that it still contained some copper, and it seems highly probable that disseminated cuprite in minute quantities accounts for both the red color and the copper content. Theoretically, further leaching would produce the common brown coloring of iron oxide. Although there is some justification, therefore, in using this

FIGURE 17.—Occurrence of red oxidation products (carrying cuprite) after chalcocite along fissures and impregnating wall rock.

red color as an indicator of the proximity of chalcocite, it must be considered only together with other known factors, such as the position of primary pyrite, zones of fracturing, leached zones, developed ore bodies, and all other data ascertainable from the developed portions of the mine, that might be used in intelligent exploration. It would serve no useful purpose to describe in detail the distribution of bodies of leached rock. Those exploring the mines are in possession of all such information. In general the positions of such leached zones are unpredictable. It is a characteristic of the ore bodies in this district that the value of the ore in a particular block is in many places impaired or strictly outlined by such leached zones.

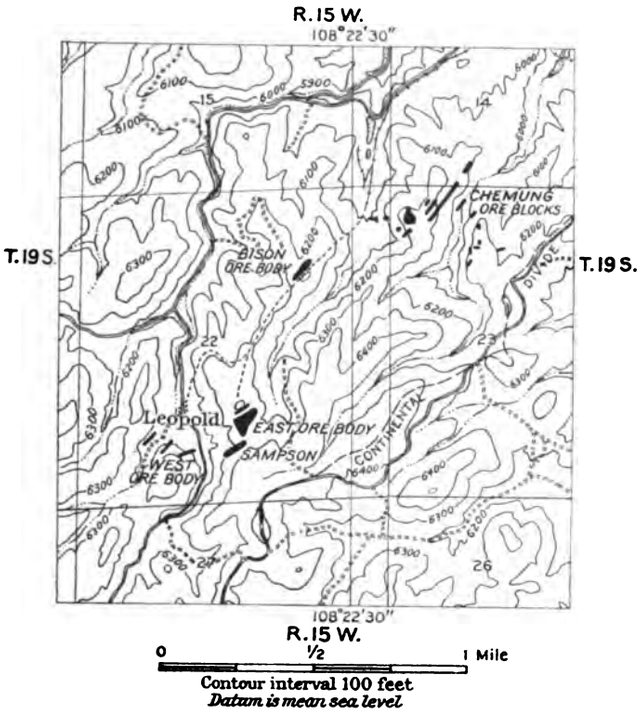


FIGURE 18.—Map showing the approximate position and form of the principal ore bodies of the Burro Mountain Copper Co.

THE ORE BODIES.

A description of the copper ore bodies of the Tyrone district is essentially a description of the properties of the Burro Mountain Copper Co. Since the field examinations were made this company has acquired the properties of the Savannah Copper Co. and thus practically all the developed ore bodies within the main fracture zone.

Of the developed ore bodies, or those which have been worked to some extent within the main fracture zone, two major groups may be recognized, and a number of less importance. One of the two major groups comprises the deposits of the old Burro Mountain Copper Co. adjacent to Leopold, among which are the East ore body, the Sampson ore body, and a number of minor deposits. The second group includes the deposits of the old Chemung Copper Co. adjacent to Tyrone, among which are a number of more or less distinct veins and blocks of ore. The positions of these several deposits projected to the surface are shown in figure 18, and the system of mine workings by which they are connected and are being developed is shown on the successive composite level maps in Plates VII–IX (in pocket).

Of the deposits which have been more or less developed but which up to the present time have proved less valuable are the several veins on the property formerly belonging to the Savannah Copper Co. but now acquired by the Burro Mountain Copper Co. These deposits are in five groups —the Oquawka and Boone mines, on the south; the Klondike mine, nearer Leopold; the workings on the Old Virginia claim; the Copper Gulf mine; and the workings about the Gettysburg and Parrot claims, about 1½ miles east of Leopold. (See Pl. VI.)

In addition to the properties mentioned, there are numerous prospects both within and outside the main fracture zone and some deposits developed by drilling which may prove in the future of economic importance.

The engineers and geologists of the Burro Mountain and Savannah companies had made before 1915 a very thorough examination of their properties by underground exploration and by drilling. Their examinations included systematic sampling of the deposits. As the shape of a chalcocite ore body is regulated by the tenor of the ore, and as its form may vary with the shifting price of

copper, the descriptions in the present report are based on data supplied by the companies, particularly the Burro Mountain Copper Co., supplemented by studies by the writer.

With the exception of the East ore body, the mines adjacent to Leopold were practically inaccessible, and the lower levels of the mines adjacent to Tyrone were flooded at the time of this study. Descriptions of these workings must therefore be quoted.

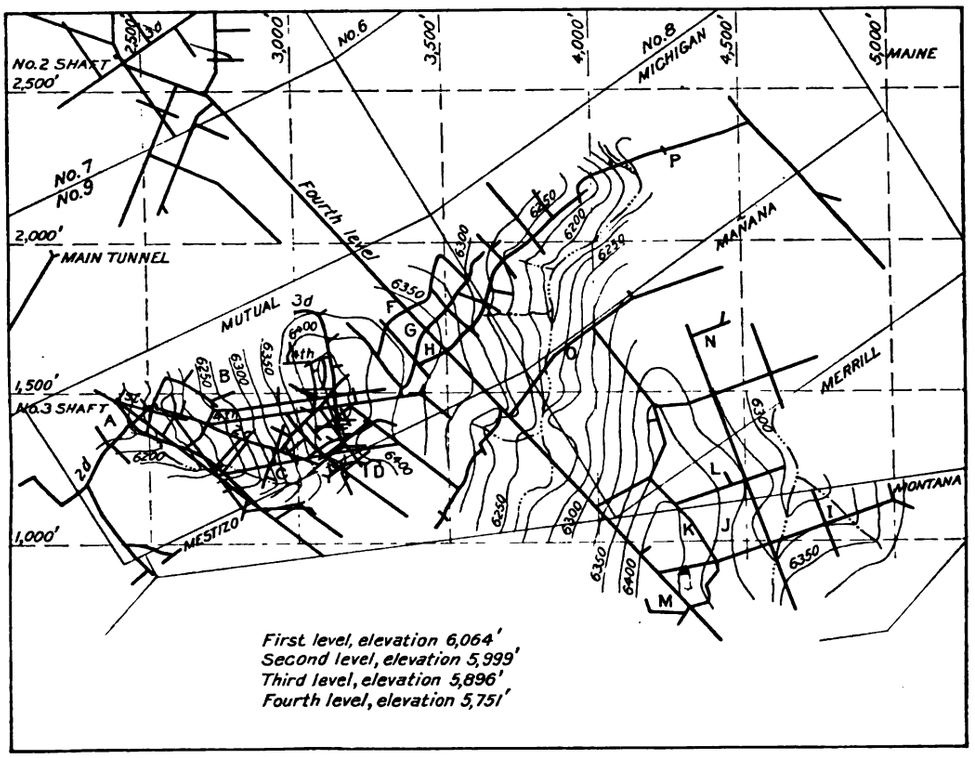


FIGURE 19.—Key map of the ore bodies near Tyrone.

MINES NEAR TYRONE.

The mines near Tyrone are developed by two shafts, Nos. 2 and 3, in Niagara Gulch. (See Pl. II, in pocket.) They open an extensive network of drives and crosscuts, illustrated in Plates VII–IX.

A third shaft, 1,500 feet to the west, does not connect with these workings or develop any considerable body of ore.

There are five levels in No. 2 shaft and six in No. 3. These levels are not evenly spaced, nor, with the exception of level No. 4, do they correspond in the two shafts. Level No. 4, however, is continuous throughout the workings adjacent to both shafts.

The relative positions of the ore bodies near Tyrone are shown in figure 19. The coordinates used in figures 19–21, 23–29 and Plate X are the same as those used on the company's maps.

Block A.—The block of ore designated block A (fig. 20) extends from a few feet above the 100 level of No. 3 shaft to a sublevel below the 200 level. The mass pitches eastward from the shaft, which it surrounds, at an angle of about 20°. It widens between the 100 and 200 levels and pinches below the 200 level. If the cross sections, as determined on the several levels by assays, are used as a basis for constructing a solid figure, the resulting mass is somewhat sphenoidal in form, being bounded by surfaces of either roughly rhombic or triangular outline, its upper western and lower eastern limits being determined by the intersection of such planes. The mass is therefore thickest at the center and narrows both upward and downward. The under side of this figure is roughly determined by a major frac-

ture trending northwest and dipping at a rather low angle to the southeast. (See fig. 20.) In seeking to explain the particular form of this ore body it must be borne in mind, first, that its boundaries are determined by a definite percentage of copper. If a different percentage were used as a basis, a somewhat different shape would result. It should also be borne in mind that the percentage of copper in the rock may vary for several reasons—differences in primary mineralization, differences in enrichment, and differences in leaching or impoverishment.

ing a reason for the limitation of ore on the south side of this block on the 200 level, two facts are significant. First, the ore terminates in both drift 29 and drift 4 against a porphyry dike; second, the pyrite at these points is not sufficiently enriched to produce ore. This dike, therefore, may have acted as a bar to active circulation and enrichment. On the north side of the ore body leaching seems to be responsible for the lack of copper.

Therefore, although the ore in this block is dependent in a measure on the position of a major fracture and a dike, portions of the ore

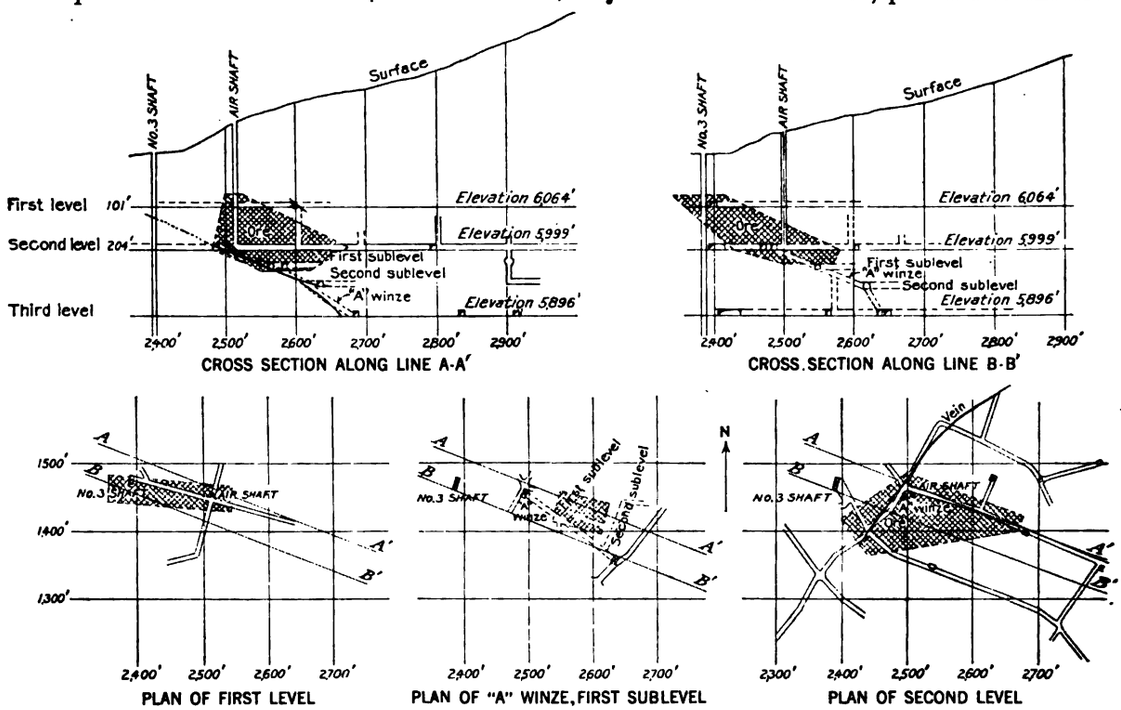


FIGURE 20.—Plans and cross sections of block A.

With these facts in mind, it is possible to point out some features that probably controlled the position of this ore body. Its base apparently conforms closely with an extensive fracture plane. Descending waters, on reaching this plane, were deflected down the dip, forming a channel along which enrichment took place. The lower limit of enrichment determines to-day the lower limit of ore. Essentially primary pyrite has been reached. To the southwest and northeast on the 200 level along this main fracture the ore terminates against leached ground. This condition also affects part of the footwall rock. In seek-

body along the major fracture, in the hanging-wall country rock, and along the north side of the body have been impoverished by leaching. The lower limits of the ore are determined by primary pyrite.

A small body of ore developed between 2-raise 3 and 2-raise 10 is apparently a part of this ore body, but leaching has reduced its volume and cut it off from the main body.

Block B.—Block B is a thin blanket of ore about 20 feet thick, lying above and below the second level about 500 feet southeast of No. 3 shaft. This ore body is connected with a rather prominent flat vein. Beneath the ore

body, on the third level, there is considerable primary pyrite, and it is doubtful if the ore ever extended to this depth. (See fig. 21.)

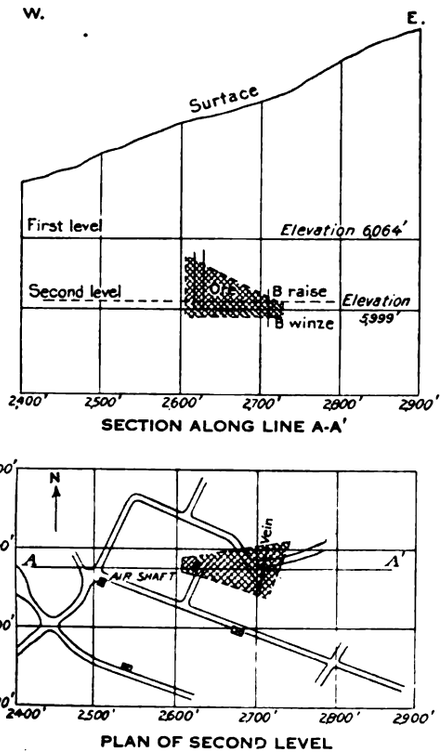


FIGURE 21.—Plan and cross section of block B.

Of special note is the leaching which limits this ore body on all sides. This is particularly well illustrated in 2-drift 4, west of drift 17, where flat-lying chalcocite veinlets are cut by vertical barren seams and veinlets. In places the leaching spreads horizontally along the chalcocite veinlets. (See fig. 22.)

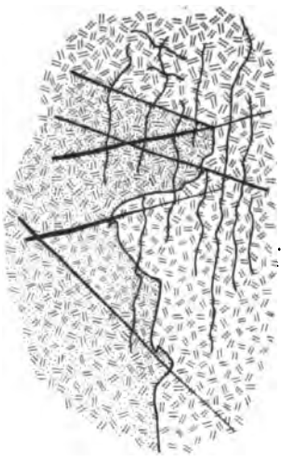
It is reasonable to suppose that this blanket of ore once extended much farther laterally. Its destruction has probably been accelerated by the canyon cutting which affects the old plain cut in rock bordering the desert, though it may have begun at a much earlier date.

Just east of this ore block there is a body of ore following a strong vein that trends N. 60° E. and dips 45°–50° SE. The chalcocite occurs both in the walls and in the vein proper. This ore body descends to a point below the third level and near sublevel B. The extension of the ore along the vein is terminated to the northeast and to the southwest by leaching—that is, descending surface waters have impoverished the vein. At the south end of sublevel B there is a rather strong fissure, probably the downward continuation of this vein; but at this level primary pyrite is exposed. Enrichment never descended to this point. This vein on the third level is joined by a parallel vein of lower dip, and considerable brecciation is evident at the northeast end in drift 26. Decided postmineral movement is indicated by broken mineralized fragments. The structural importance of this vein lies in its relation to the block of ground beneath or west of it. The vein appears to form a hanging wall of what was once an extensive block of enriched ground.

Breccia ore body.—The Breccia ore body is about 750 feet east of shaft No. 3 and extends from a point 10 feet above the third level to a point 100 feet or more below the third level. (See fig. 23.)

The ore occurs within a mass of brecciated country rock—granite and intruded porphyry dikes. On the third level and sublevel B the ore is almost coextensive with the breccia, but lower down the breccia, though heavily mineralized, is not enriched.

In the section on fracturing (pp. 18–19) the origin of this breccia is discussed. Attention will be directed here to certain major lines of fissuring that may be related to the breccia.



Sericitized porphyry cut by veinlets of pyrite and chalcocite

Kaolinized porphyry cut by limonite-quartz veins; copper has been leached

FIGURE 22.—Leaching of chalcocite veinlets and wall rock.

On the second level there is a strong vein following drift 28 which is recognized as the footwall of the ore bodies east of it. This line of disturbance may be recognized in somewhat equivalent fractures on the third level just west of drift 25, and there is a suggestion here that the northeast continuation of this system cuts drift 16 between drift 29 and drift 22. In this connection it is of interest that the Breccia body terminates at this place—that is, just south of drift 29—where also it is in

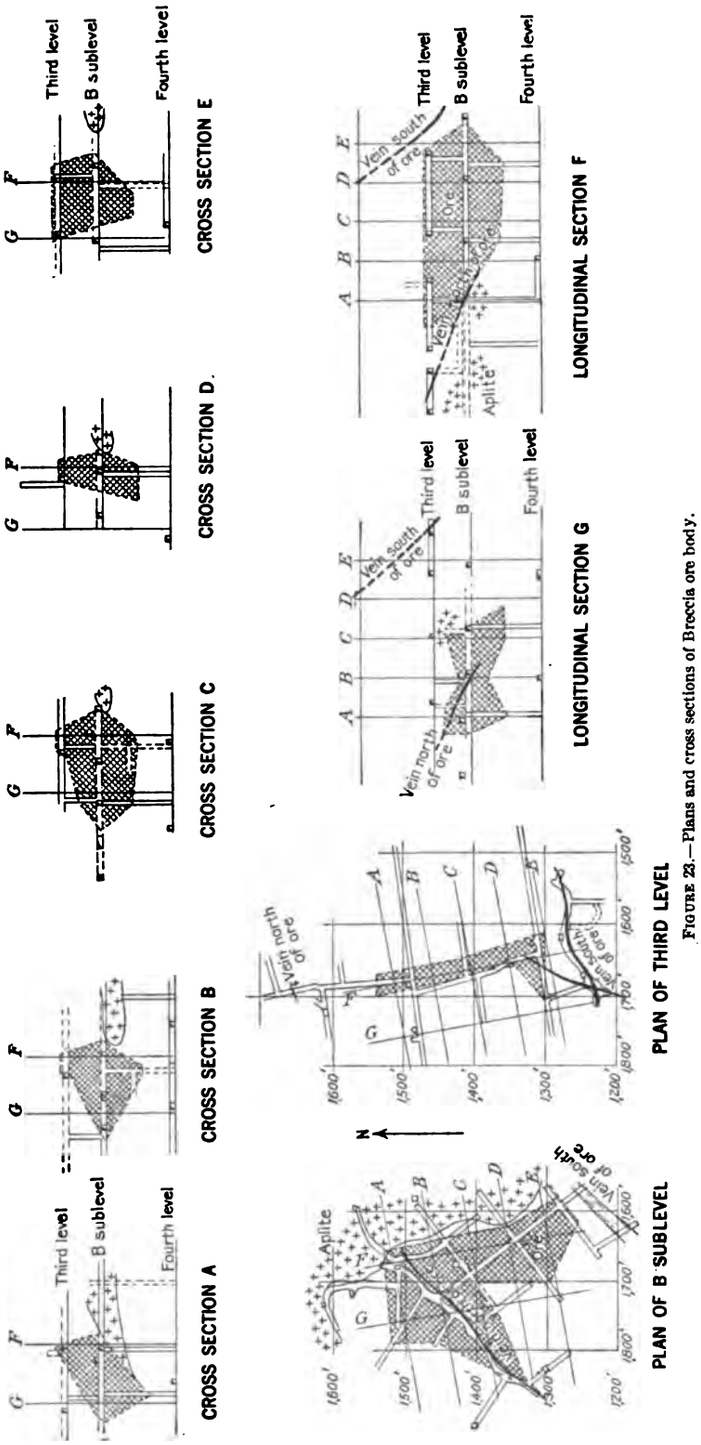


FIGURE 23.—Plans and cross sections of Breccia ore body.

contact with a dike of considerable size exposed in the drift to the north. This fracture system therefore is a footwall boundary for all this mineralized ground. On sublevel B a strong fissure traverses the breccia near its northern limit and may well belong to this same system or region of crushing. Here, however, there is more breccia to the north, or in the footwall; and lower down, on the fourth level, this condition is more noticeable, for the north extension of the breccia lies north of the point where this fracture system should appear.

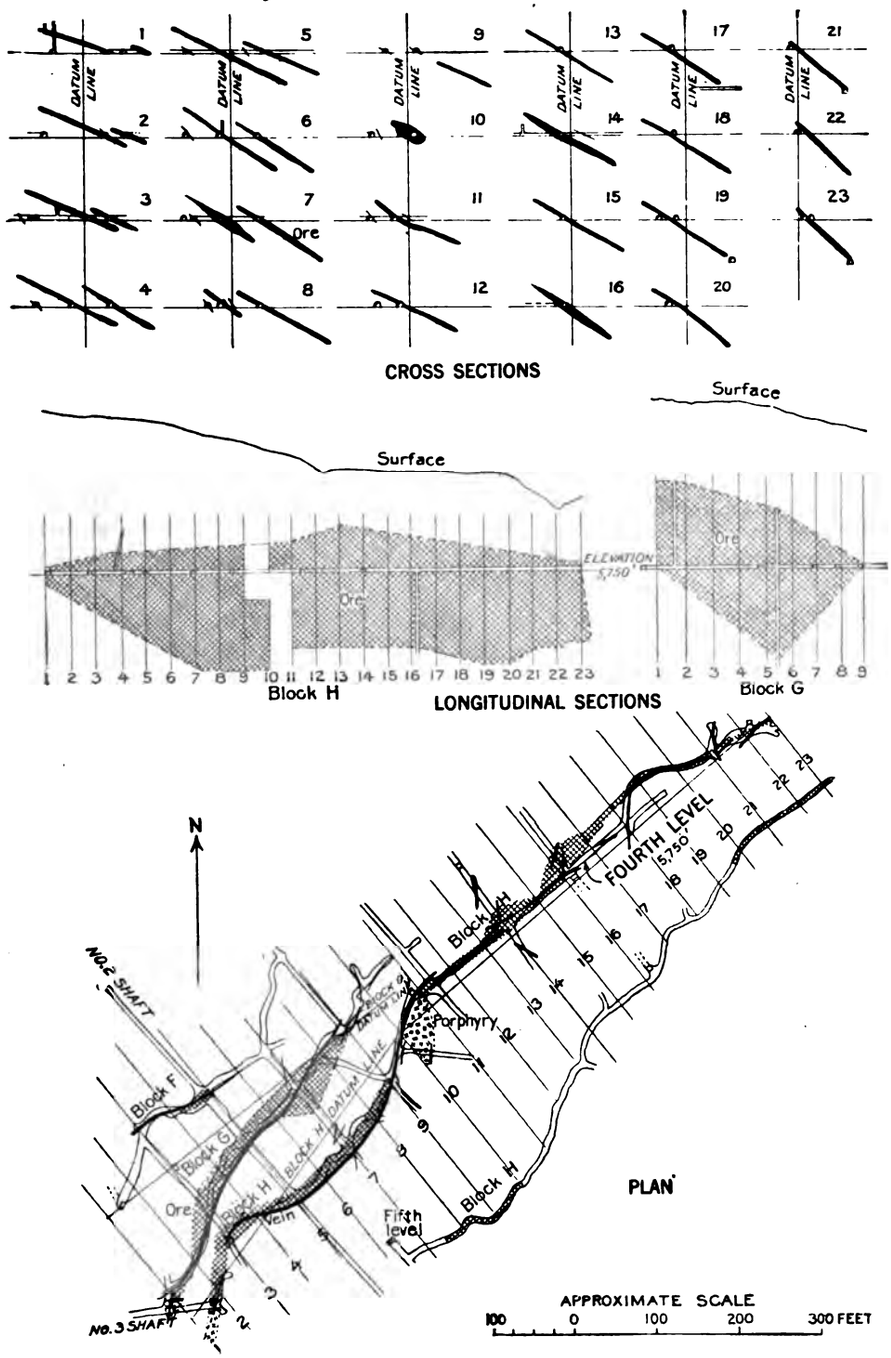


FIGURE 24.—Plan and sections of so-called flat veins on fourth level

A second important fracture system is noticed first on level No. 2 as a hanging-wall

feature. Beneath it and between it and the footwall system just mentioned are all the ores on this level. On the third level it appears as a prominent vein system overlying the Breccia ore body. On sublevel B the workings do not reach it, but on the fourth level its downward continuation may be recognized with considerable certainty, and here it corresponds to the south end of the brecciated country rock. From these facts it would appear that the Breccia body, though following a line of dislocation nearly at right angles to the prevailing strong fissures in this vicinity, is contained within a block limited by two very prominent zones of movement. As suggested above, this broken piece of ground probably resulted from collapse connected with distention of the crust during intrusion.

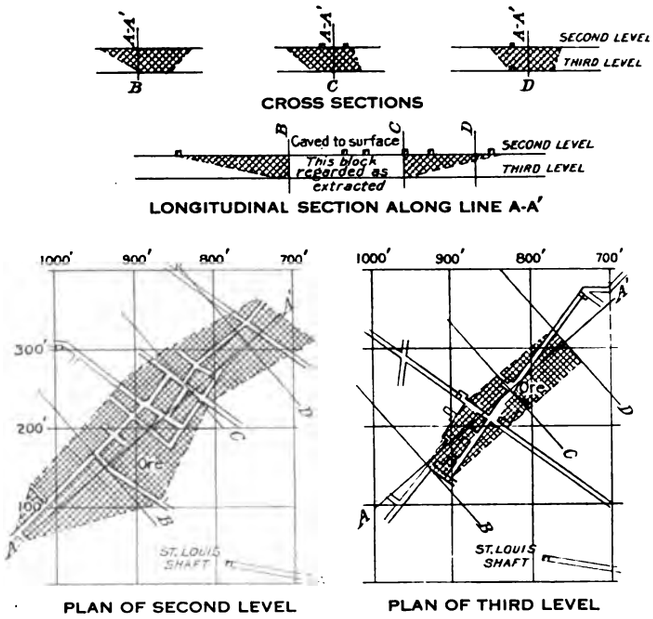


FIGURE 25.—Plans and sections of Protection ore body.

Veins on fourth level.—Three veins are developed on the fourth level. (See fig. 24.) They constitute roughly parallel ore bodies of considerable importance. The northwest vein (footwall vein) strikes N. 60° E. and dips about 30° SE. The middle vein and the southeast vein (hanging-wall vein) strike on the average about N. 40° E. and dip about 40° SE. The plane of these two veins is a warped surface, and their strike therefore varies from place to place.

As in all other parts of these mines, a fissure is not formed by a simple break but involves numerous anastomosing veins. The vein systems are simply places where the greatest movement has taken place within blocks of thoroughly shattered ground.

Between the eastern (hanging-wall) and middle vein the rock is sufficiently impregnated with chalcocite to make ore. The quantity of ore ultimately extracted will depend on the price of copper. In many of the workings on the fourth level in the vicinity of these veins primary pyrite, scarcely or not at all enriched, is common. Obviously on veins enrichment descends deeper than in the less fractured wall rocks. Oxidation, which is a later feature, is attacking the unenriched pyrite, as well as the veins, a fact which supports the view expressed above that present conditions of oxidation in these deposits are radically different from those existing when the chalcocite was formed. The erosion and canyon cutting now in progress are permitting the surface waters to remove chalcocite.

Other bodies.—East of these three veins are a number of isolated occurrences of ore, seven in all, connected for the most part with prominent fractures. Their location is indicated on figure 18 (p. 40). Also 300 feet east of shaft No. 2, on the fourth level, and 500 feet S. 10° E. from the shaft, are small bodies of ore in brecciated granite. There is nothing unusual in their occurrence, and they will not be further mentioned. The possibilities for development of additional ore are discussed below (p. 51).

MINES NEAR LEOPOLD.

With the exception of the East ore body, the deposits near Leopold were practically inaccessible in 1915, and the following descriptions are taken from a report on the properties by E. F. Pelton.

Protection.—The Protection ore body (fig. 25) is 900 feet N. 75° W. from the Sampson shaft, between the second and third levels.

It is about 400 feet long and from 50 to 80 feet wide. A part of its central portion has been extracted. It is evident from the plans of the second and third levels that the size of the deposits decreases in depth, and that probably little ore will be developed below the third level. Exploration to the northeast and southwest, however, may discover more ore.

St. Louis.—The St. Louis ore body (fig. 26) is a small deposit 600 feet N. 75° W. from the Sampson shaft, between the second and third levels. The ore follows a strong N. 60° E. vein that dips 40° SE. It is lean below the third level.

West.—The West ore body (fig. 27) is part of the pillar of the Sampson shaft. It extends westward about 750 feet between the first and fourth levels. What remains of the ore body consist of scattered blocks left from previous square-set stoping. About 75 per cent of the ore is now below the third level. The West ore body follows a strong N. 70° E. footwall vein dipping 30°–45° SE. The width and good grade of the stopes are partly accounted for by intersection with a N. 20° W. system of fractures.

Sampson.—The Sampson ore body (fig. 28) is 400 to 800 feet east of the Sampson shaft, between the tailing tunnel and the fourth level. It now consists of scattered blocks left from previous stoping. About 75 per cent of the ore remaining lies in a fairly compact block toward the east end of the ore body. It is clear that this ore body also is connected with a system of fractures dipping southeastward.

East.—The East ore body (Pl. X) is 900 feet east of the Sampson shaft. It extends from the oxidized zone 25 feet above the second level to unenriched pyrite about 20 feet below the fifth level. It is an irregular block with a maximum thickness of 210 feet, overlain by about 225 feet of soft kaolinized barren porphyry. If it is like the Sampson and West ore bodies, there will be found at its top a gradation from good chalcocite ore to barren oxidized ground through a distance of about 14 feet.

The St. Louis vein,[41] which forms the northern footwall of this ore block, extends from the second level to a point 30 feet below the

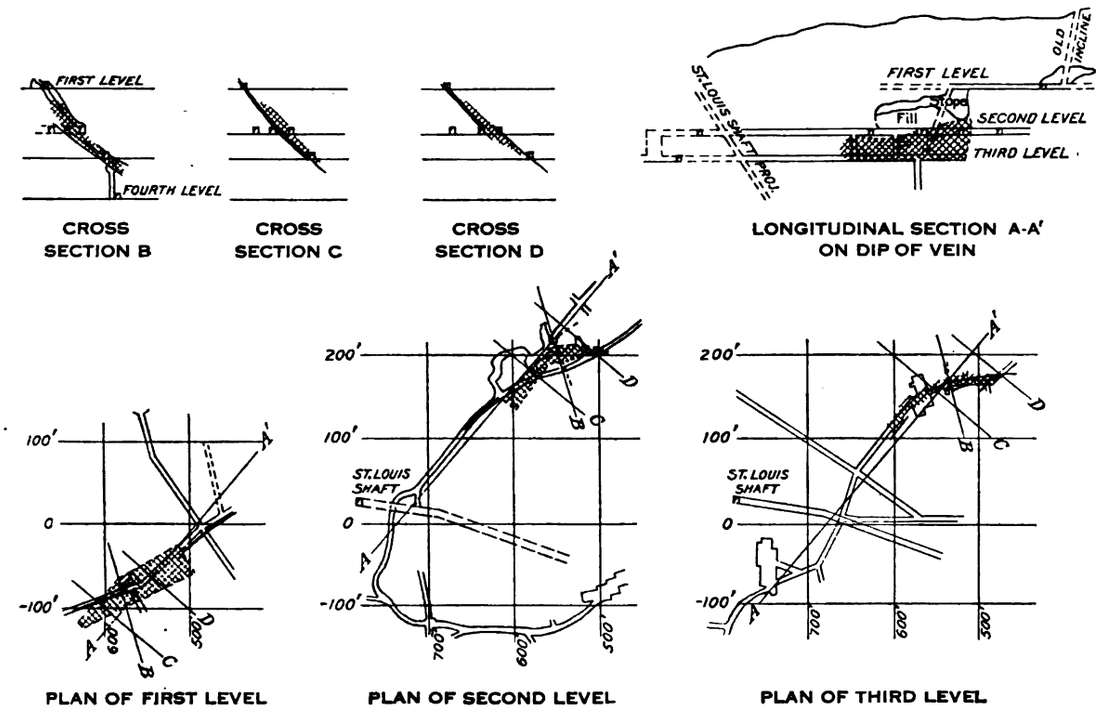


FIGURE 26.—Plans and sections of St. Louis ore body.

[41] Not to be confused with the St. Louis ore body, west of the Sampson shaft.

fifth level. The ore-bearing portion is about 200 feet long, 100 feet high, and in places 30 feet thick. It dips about 45° SE., and the pitch of the ore is about 23° NE. (See Pl. X.)

The northern boundary of this ore body follows the southeastward-dipping St. Louis vein, and the western limb is defined by the North vein, which trends west of north and dips at a low angle to the east. These two systems determine the strong pitch of the ore body to the south and east.

Bison.—The Bison ore body is about 400 feet long, 60 feet wide, and 50 feet high. The country rock is granite with porphyry dikes. The ore body is isolated and lies about 200 feet west of the main tunnel and about 1,500 feet southeast of the portal. There is no unusual feature about this ore body. A plan and cross section are given in figure 29, and the azimuth of the principal fractures in Plate IV (p. 16).

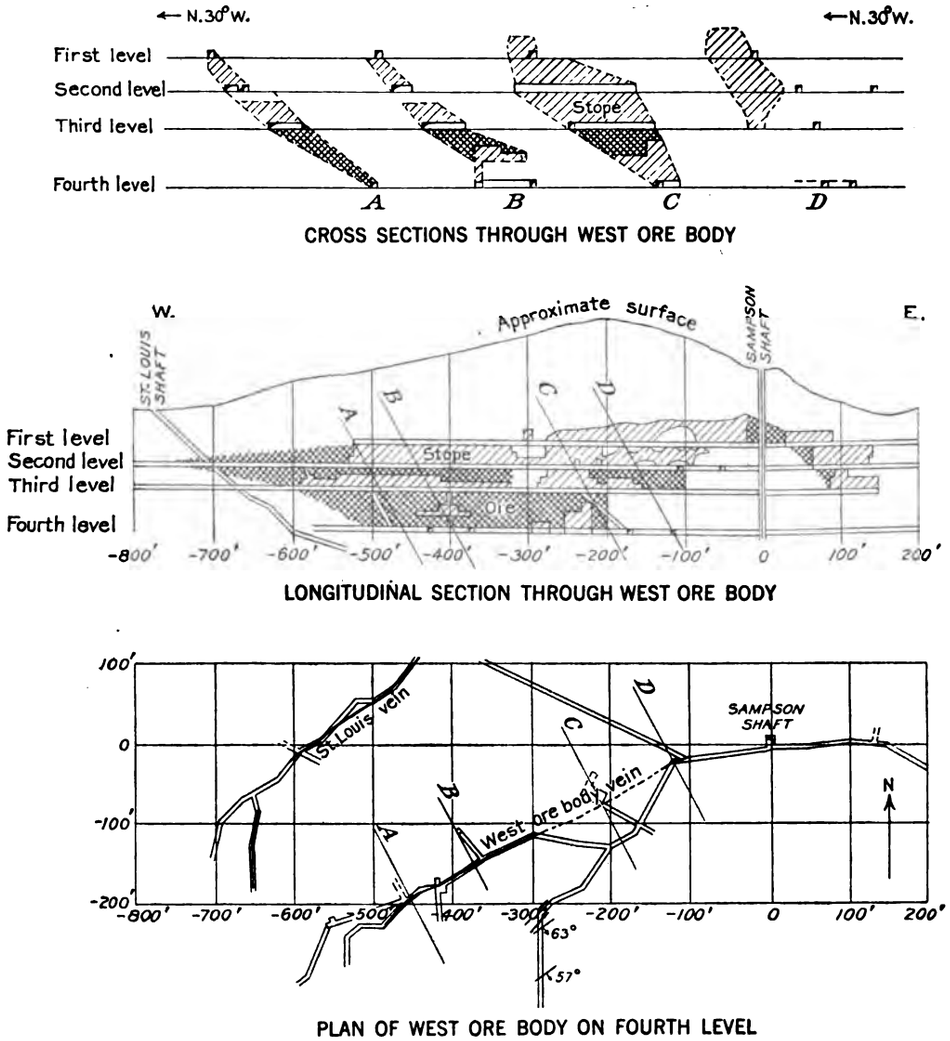
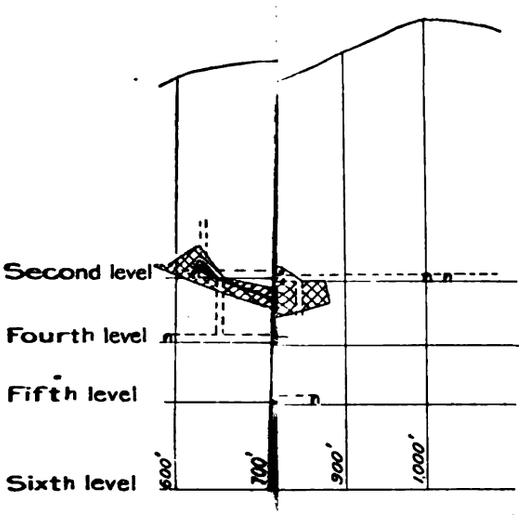


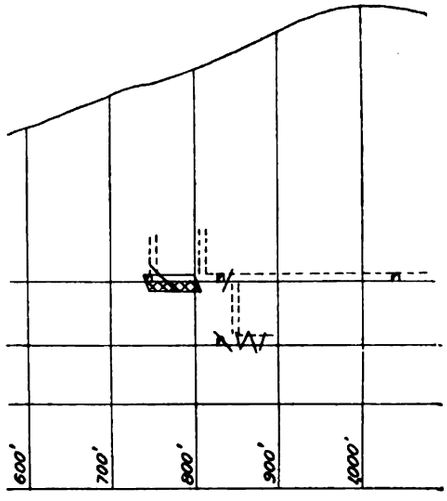
FIGURE 27.—Plan and sections of West ore body.

OLD WORKINGS ON THE GROUND OF THE SAVANNAH COPPER CO.

On Plate VI (in pocket) is shown the location of a number of prospects or mines that are now no longer operated. The following notes are presented as a matter of record. It is doubtful if any of these prospects will be operated except when copper sells at a very high price.



CROSS SECTION THROUGH E.-W. LINE 300'



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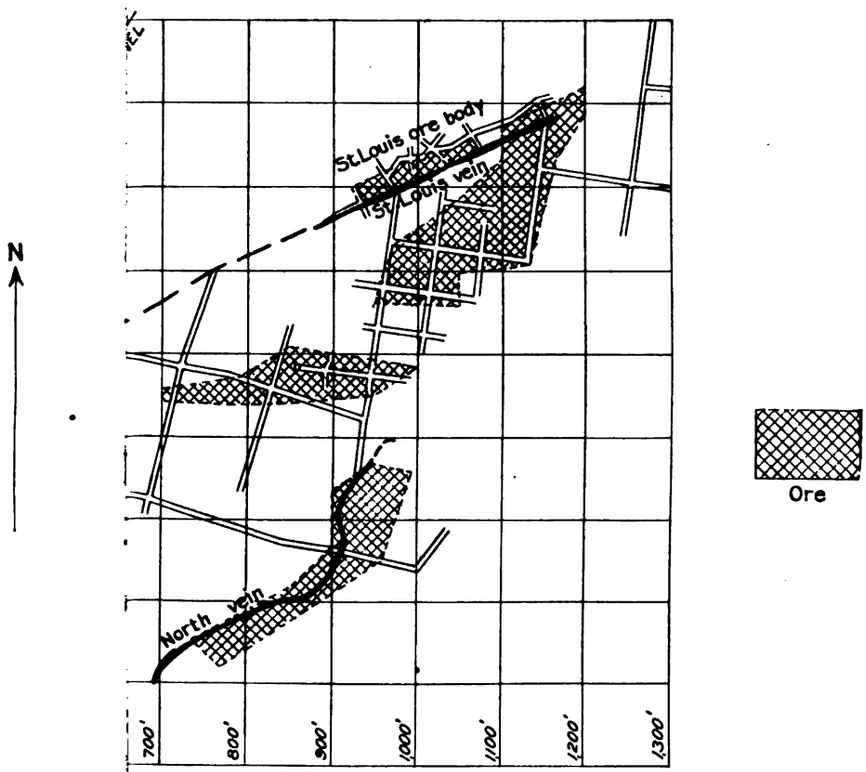

PLAN OF EAST ORE BODY ON FIFTH LEVEL

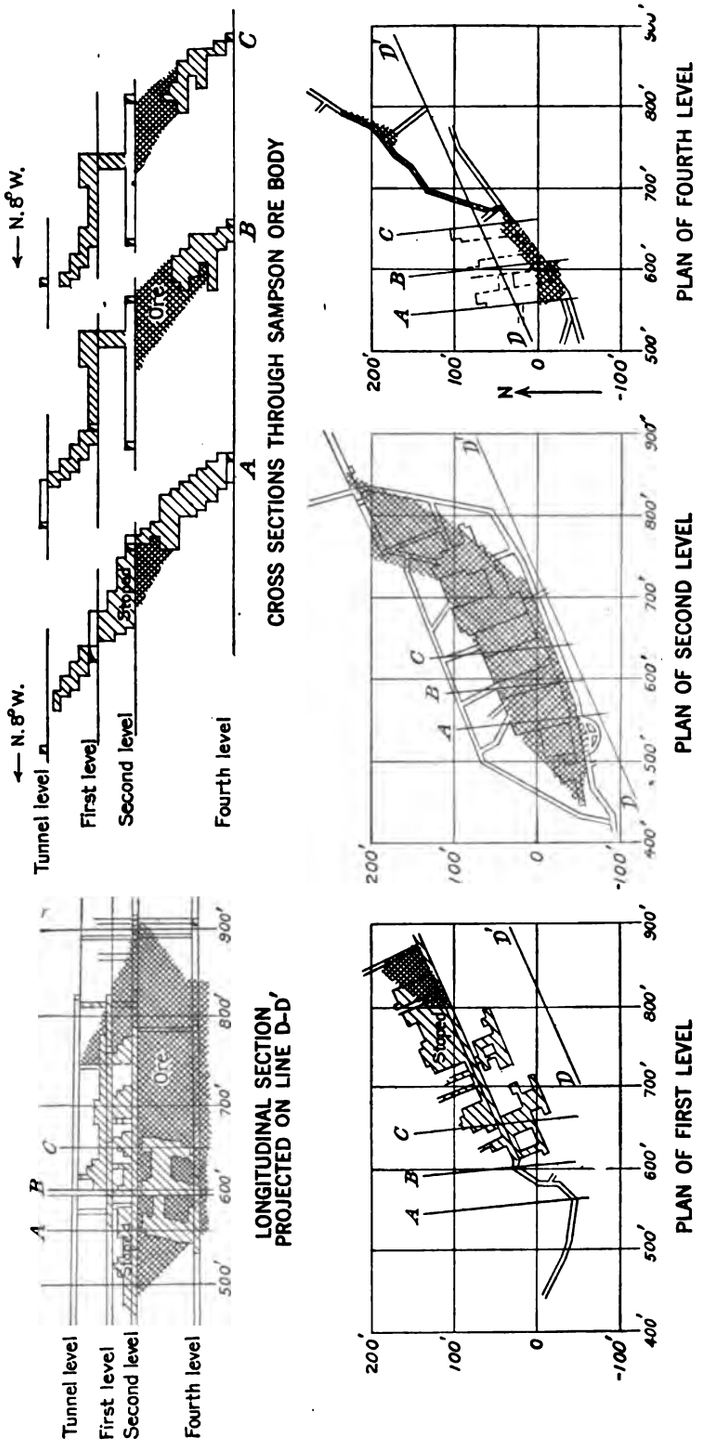

FIGURE 28.—Plans and sections of Sampson ore body.

At the Oquawka mine 300 to 400 tons of 4 per cent chalcocite occurred in a vein dipping 60° N. There was no ore at the 300-foot level. The tenor of the ore decreased in a 30-foot winze from the 200-foot level.

At the Boone prospect a north-south vein dips 80° E. Carbonate ore running as high as 30 per cent in copper was shipped, but the prospect did not turn out well.

At the Klondike mine a north-south vein has been mined to a depth of 60 or 70 feet, where primary pyrite was found.

At the Copper Gulf there is a vein carrying a little copper, with some oxidized ore at the surface.

TENOR OF THE ORE.

The minimum amount of copper in the rock necessary to constitute ore in the Tyrone district, as elsewhere, is determined by a balance between total costs of mining and the price of copper. In 1915 prospective tonnages had been calculated on three different bases, a minimum of 1.75, 2.00, and 2.25 per cent. At that time rock containing 2 per cent was considered ore. A considerable tonnage had been blocked out averaging 3.16 per cent, more than twice as much averaging 2.31 per cent, and these two amounts together averaged 2.58 per cent. By reducing the minimum to 1.75 per cent these tonnages were doubled. Just what percentage of copper the rock must contain to be considered ore will therefore depend on many factors, among which the price of copper is all-important.

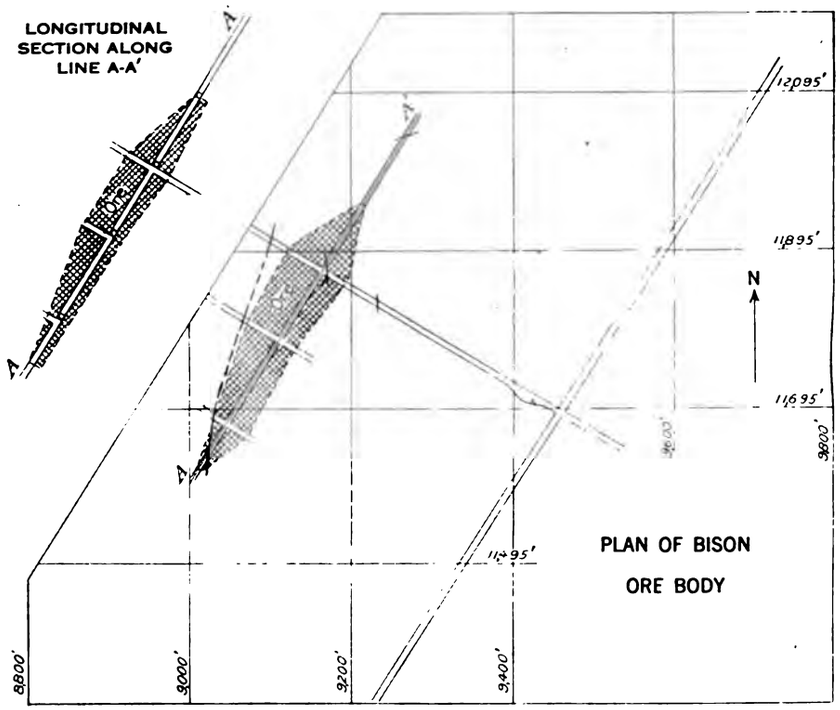

FIGURE 29.—Plan and section of Bison ore body.

At the Old Virginia workings an east-west vein dips 45° N. There are four or five levels. Water stands 25 feet below the collar of the shaft. The vein is stoped for a length of about 100 feet between the surface and the 100-foot level. The ore was carbonate and averaged better than 10 per cent of copper. The change to chalcocite takes place at about the 100-foot level.

The workings of the Gettysburg mine were not accessible. The shaft is an incline dipping south in the vein. There is a drift on the vein at a depth of 300 feet, but the prospects are not good. A little ore was found from the surface down to a depth of 60 feet.

PROSPECTS FOR ADDITIONAL ORE BODIES.

Exploration east of the developed territory, by drilling, has not been very encouraging. The physiographic history of the region points

to a briefer period of enrichment to the east, under the gravels, than in the area to the west. Moreover, results of mining show that there is some lowering of grade of the ores progressively eastward, thus supporting the theoretical considerations.

Ore should be more plentiful under the hills than in the valley, there having been less impoverishment there by erosion and the accompanying leaching.

The fractured and altered rocks across the Mangas Valley may be intrusives of later age than the quartz monzonite porphyry at Tyrone, and this fact must be considered in speculating on the possibilities of ore in those rocks. If they are younger than the Tertiary lavas, then the prospect of finding ore in them is lessened, for nowhere in the Silver City region have commercial bodies of disseminated copper ore been found in these late intrusives. The intense alteration of these rocks, however, makes their character and age uncertain. Structural relations whereby a decision might be reached as to this point were not discovered. Such petrographic evidence as could be gleaned from studies made with a microscope indicates that the rocks represent a later period of intrusion.

Prospecting will probably then most profitably be confined to the principal zone of fracture, and within this zone to those portions of most intense fracture, under hills and in the general region between Leopold and Tyrone. The areas farther south, in the ground formerly controlled by the Savannah Copper Co., are in a measure already prospected by drill holes and shafts. That portion of this territory, under hills, which has not been prospected deserves at least a certain amount of preliminary drilling.

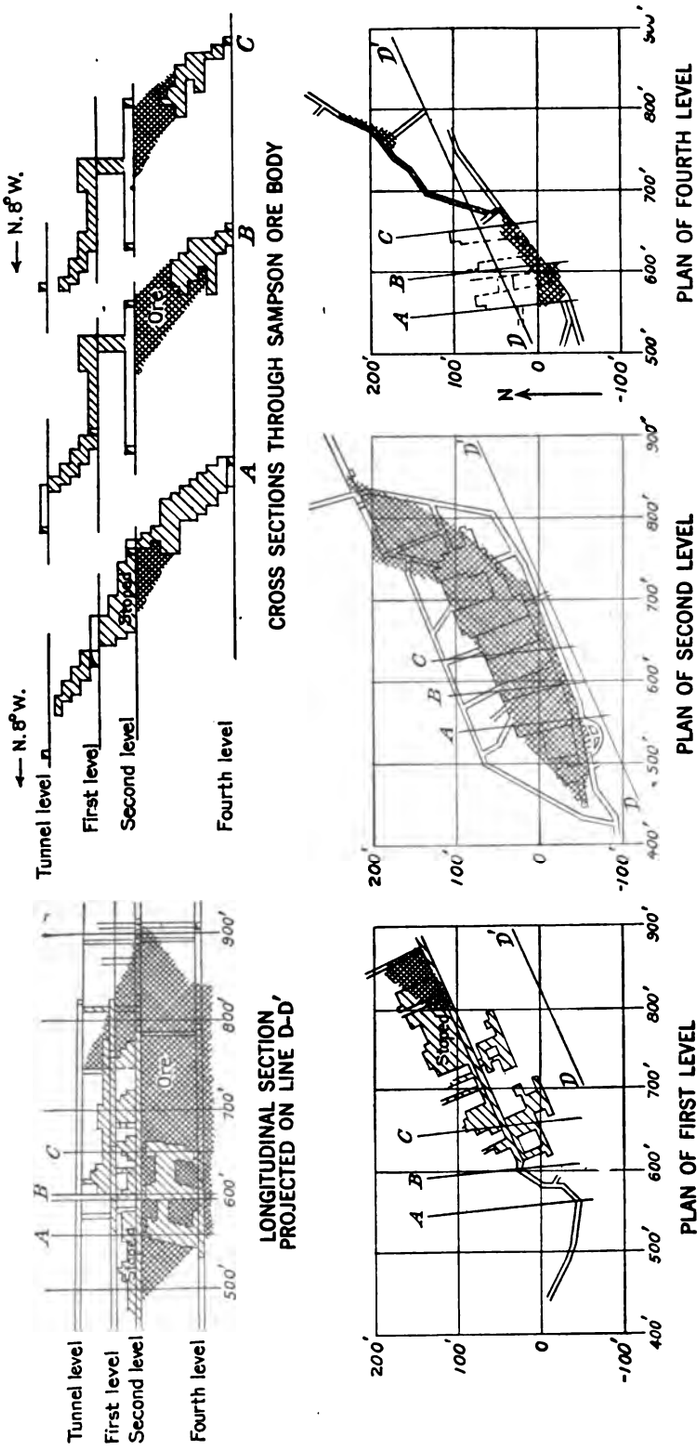

FIGURE 28.—Plans and sections of Sampson ore body.

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DEPARTMENT OF THE INTERIOR
ALBERT B. FALL, Secretary

UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, Director

Professional Paper 123

125

A SUPERPOWER SYSTEM FOR THE REGION BETWEEN BOSTON AND WASHINGTON

PROPERTY OF
CARL H. LANGE
PETROLEUM GEOLOGIST AND ENGINEER
SAN FRANCISCO

BY
W. S. MURRAY AND OTHERS

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FOREWORD.

By George Otis Smith.

In December, 1918, President E. G. Buckland, of the New York, New Haven & Hartford Railroad Co., at the instance of Mr. W. S. Murray, consulting engineer, of New York City, urged upon Secretary of the Interior Lane a survey of the sources of energy in New England and on the Atlantic seaboard as far south as Washington. Secretary Lane's response was that general and local studies of the country's available power had been pushed with vigor by the Geological Survey as a war measure and that the continuation of this work was already planned under a special appropriation asked from Congress, but as the plans had not contemplated work on the scale suggested by Mr. Buckland the Secretary invited conference and advice, for he at once saw the advantage of making this intensive analysis and working out a plan to provide for the ever-growing energy requirements of this industrial region.

On January 27, 1919, the Secretary of the Interior sent to Congress a supplemental estimate of "an appropriation in the sum of $200,000 for a special investigation and report on the power supply for the Boston-Washington industrial region, to be made during the fiscal year 1920." Explanatory letters in which a constructive national power policy was urged were addressed to the chairmen of the committees on appropriations. "The country," said Secretary Lane, "is now passing through a period of transition, which, I firmly believe, will soon be followed by one of industrial activity and expansion. The enormous development of war industries had created an almost insatiable demand for power, a demand that was overreaching the available supply with such rapidity that, had hostilities continued, it is certain that we should now be facing an extreme power shortage. Happily such a crisis was averted by the signing of the armistice, and the ensuing curtailment in the demand for war materials has carried us past immediate danger of a power famine in the industrial districts of the Northeast."

The Director of the United States Geological Survey was heard on the proposal January 30 before the Appropriation Committee of the House. The proposal excited interest but lacked wide support, and the committee failed to report the item for further consideration by Congress.

During 1919 the subject of power conservation was fully discussed before engineering societies and trade and commercial bodies and in the technical and financial journals, so that the appropriation item was better received at the next session of Congress. Mr. Murray, who had accompanied Mr. Buckland in the earlier conference with the Secretary of the Interior, was foremost in winning both popular and professional support for the idea, and the strongest presentation of the subject to the House Committee on Appropriations was made by a committee appointed by the Engineering Council, of which Mr. Murray was chairman and L. P. Breckenridge, professor of mechanical engineering, Yale University; D. C. Jackson, professor of electrical engineering, Massachusetts Institute of Technology; and M. O. Leighton were the other members.

An appropriation of $125,000, carried in the sundry civil appropriation act for the fiscal year 1921, among the items under the United States Geological Survey, authorized the proposed investigation in the following language:

> For the survey of power production and distribution in the United States, including the study of methods for the further utilization of water power, and the special investigation of the possible economy of fuel, labor, and materials resulting from the use in the Boston-Washington industrial region of a comprehensive system for the generation and distribution of electricity to transportation lines and industries, and the preparation of reports thereon, $125,000. The Secretary of the Interior is authorized to receive any sums which may be contributed for this purpose. Such sums shall be deposited in the Treasury and credited to the appropriation herein made and be available for expenditure for the purposes thereof.

The work was promptly organized, and a strong engineering staff was selected by Mr. Murray, who had been appointed by the Secretary of the Interior as the logical man to head this engineering study. The engineers appointed to assist Mr. Murray have met every expectation, and great credit is due to them for their tireless enthusiasm for the work, inspired by both professional and public spirit, and to Mr. Murray for his wise choice of associates. Chief Hydraulic Engineer Grover, of the United States Geological Survey, and Chief Mechanical Engineer Hood, of the Bureau of Mines, became members of the engineering staff, so as to coordinate this special study with the current investigations of the Federal bureaus. This special short-period study was administered as a unit under the water-resources branch of the Geological Survey.

Secretary of the Interior Payne added to the driving force of this intensive study an advisory board consisting of men of vision and experience, representing our railroads, both steam and electric, and manufacturing, engineering, and chemical industries. These busy men held eight meetings during the year—a service that has added value to this report as now presented. The legal and financial aspects of the superpower project formed the subject of discussion at several of the meetings of the advisory board, but the formulation of conclusions on these aspects was deemed inopportune without further consideration, which it is proposed may be given by the board under authority of new appointments by Secretary of the Interior Fall.

The cooperation of all the industries affected by the proposed larger electrification was unstinted. Engineering aid was freely given, data were promptly furnished, and money was generously contributed as needed. No "dollar-a-year" men were engaged on this work, but under the specific authority of Congress $26,000 was contributed by 36 corporations and individuals representing utilities and industries in the zone.

The advisory board, under the leadership of Prof. Breckenridge, was kept fully informed of each step in the engineering study of the problem, and the active interest of many of the members led to constructive criticism, but no further responsibility for the conclusions here reported can be placed upon the advisory board. For the work done in the engineering staff a division of responsibility and credit is necessarily difficult, as here a group of workers has thoroughly coordinated its endeavors. In the appendixes to the report the responsibility of authorship has been indicated so far as possible, but the credit for the successful issue of the year's work must be given to the staff as a whole.

The investigation was begun on July 1, 1920, and the report was completed on June 30, 1921, as contemplated by Congress, a result in itself creditable to all connected with this special study.

JUNE 30, 1921.

A SUPERPOWER SYSTEM FOR THE REGION BETWEEN BOSTON AND WASHINGTON.

By W. S. Murray and others.

SUMMARY REPORT.

By W. S. Murray.

INTRODUCTION.

On first presenting the subject considered in this report to the late Secretary of the Interior, the Hon. Franklin K. Lane, I used the word "superpower" to describe a system that would furnish power to the railroads and the industries within the territory between Boston and Washington that has now become more familiarly known as the superpower zone. (See Pl. I.) The system in turn has become known as the superpower system, and as the investigation has progressed it has taken the form of a proposed entity capable of incorporation as either one or more superpower companies.

My association with the power business during the last 15 years in the electric utility, railway, and manufacturing fields had so forcefully impressed upon me the unnecessary waste of money, labor, and material incident to the present form of power production by unassociated units that it seemed a constructive move in the interest of large national economy to present a plan for coordinated power production which would prevent this waste.

In reading this report two things should be kept in mind—first, that the economy in power production and distribution thus far attained has been due largely to the electric public utilities; second, that the failure to attain the highest possible economy has been due largely to restrictive policies that have inhibited the expansion of electric public utilities.

If this report accomplishes nothing more than to show the saving in labor, material, and money that could be effected by the installation of a power system adequate to serve both the railroads and the industries in the superpower zone, then, by the token of this saving, I plead in the name of national economy for a broad policy in legislation, regulation, financing, and management that may not only remove the existing inhibition but may give positive encouragement to the expansion of electric utilities, especially within this zone, so that adequate, reliable, and cheap power may become available to permit the normal expansion in our industries, together with economical expansion in the capacity of our railroads to handle the increased tonnage incident thereto.

The physical details of the plan proposed are given under the heading "The superpower system" (pp. 13–15); but, in order that the true objective may not be lost and that the functioning of the whole, with its total result, may be comprehended, it should be remembered that the superpower system is nothing more than a superutility. All its parts will be fashioned similarly, like the parts, for example, of the New England Power Co., with its 12 power stations and its 750 miles of transmission lines; but owing to the greater capacities and distances involved in the superpower system, its generating units and transmission lines will be larger and more efficient than those now in use. It will make no difference whether the system is a single great superutility or several utilities built up separately and functioning in close relation to one another. In applying the principles to be set forth in this report the superpower system should be visualized as one great power project serving the superpower zone.

SUMMARY OF CONCLUSIONS.

The market for superpower energy will be furnished by the electric utilities, the industries, and the railroads. The estimated requirement for energy supplied through the electric utilities for municipal, private, industrial, and railroad purposes in 1930 is 31,000,000,000 kilowatt-hours. This energy could be supplied by a coordinated power system such as is described in this report at an annual cost of $239,000,000 less than by an uncoordinated system such as is now in use. This amount represents the net saving after the necessary fixed charges on total capital expenditure have been deducted. The cost of uncoordinated power production in 1930 is computed from the cost of the present system in 1919. The total investment in generating and transmission facilities for the superpower system will be $1,109,564,000, of which $416,346,000 will represent the value of existing facilities to be incorporated into the system.

A study of the 96,000 manufacturing establishments operating within the superpower zone shows that by 1930, through the maximum economical use of purchased electric energy, they can save $190,000,000 annually above the fixed annual charges against a capital investment of $185,000,000 to provide the motor equipment necessary to receive and use this power.

The combined capital investment necessary for the electric utilities and the industries as of 1930 therefore amounts to $1,294,564,000, and this total investment will yield annually above the fixed charges the sum of $429,000,000, or 33 per cent on the investment.

Within the superpower zone there are 36,000 miles of railroad measured as single track—that is, including each track of main lines, yards, and sidings. Of this total about 19,000 miles can be profitably electrified, so as to yield by 1930 an annual saving of $81,000,000 as compared with the cost of operation by steam. The capital expenditure necessary to electrify the 19,000 miles would be $570,000,000, and the average return upon the investment would therefore be 14.2 per cent.

As defined in another section of the report, the superpower system begins at the generating stations connected to its lines and ends at the busses of existing electric utilities. Therefore, the cost of power discussed in this report means cost at the busses of the electric utilities and must not be confused with the cost to the ultimate consumer, which is necessarily much greater, owing to the added cost incident to secondary distribution systems.

Studies of the operations of each load center have shown that a large quantity of coal could have been saved had superpower facilities been available in 1919. On comparing the coal rates of power production in 1919 with those of the superpower system and applying the difference to the load that will exist in 1930 we find that the coal saved annually under the superpower system may be estimated as follows:

	Short tons.
Electric utilities	19,149,000
Heavy-traction railroads	10,210,000
Manufacturing industries	20,625,000
	49,984,000

The order in which the superpower steam-electric and hydroelectric power plants and transmission systems should be constructed must depend (1) on the present industrial demand for energy that can not be satisfied because of the difficulties of the local electric utilities in financing extensions; and (2) on the future demand for energy that will result from the more economical generation of power under the superpower system.

Many of the economies incident to superpower operation will be effected through the interconnection of existing plants and systems, and these economies should be increased as new power plants and interconnections are added. Certain steam plants that are under consideration and others that are under construction will be when completed as efficient as the proposed base-load steam-electric plants of the superpower system. Notable among these plants are the Hell Gate station now being constructed by the United Electric Light & Power Co. of New York City and the Delaware station of the Philadelphia Electric Co. However, by keeping in mind the two conditions, already stated, that should govern the order of construction, it is believed that the quickest return will be obtained by following in chronologic sequence the order of procedure outlined on page 13.

1. The construction of a steam-electric plant near Pittston, Pa., to supply a part of its energy to the Anthracite division of the superpower zone and the remainder to the Metropolitan division, particularly New Jersey.

2. The construction of a steam-electric plant near Sunbury, Pa., to supply a part of its energy to the Anthracite division, a part to the Reading load center, and the remainder to Philadelphia.

3. The construction of hydroelectric plants on Delaware and Susquehanna rivers to supplement the steam plants indicated in paragraphs 1 and 2.

4. The progressive development of the Hudson River projects to meet the growth of energy requirement at the Schenectady, Utica, Poughkeepsie, and Pittsfield load centers.

5. The construction of a steam-electric plant near Boston to supply the Boston, Lowell, and Newburyport load centers.

6. The construction of a steam-electric plant near New Haven to supply the New Haven, Bridgeport, Waterbury, and Norwich load centers.

7. The partial construction of the first hydroelectric plant in the development of Potomac River as soon as the power demands of the Baltimore and Washington load centers require additional plant capacity.

Plant capacities are not stated above, as they can not be finally determined except by further and more detailed study of local conditions combined with regional demands. The load growth at all the centers, however, will make it imperative to provide new plant capacity at an early date, so that the construction of additional plants, as detailed in Appendix E, must be started promptly after the plants that will yield the greatest return have been built.

THE SUPERPOWER SYSTEM.

The territory in which the superpower survey has been made—the "superpower zone"—may be described as lying between the thirty-ninth and forty-fourth parallels of latitude and extending from the coast approximately 150 miles inland, embracing parts of the States of Maine, New Hampshire, Vermont, New York, Pennsylvania, Delaware, and Maryland and all of the States of Massachusetts, Rhode Island, Connecticut and New Jersey. (See Pl. I.) Within this zone is concentrated one-fourth of the population of the United States, and within it are operated, most of them independently, 315 electric utilities, 18 railroads, and 96,000 industrial plants. The superpower zone is the finishing shop of American industry.

Unlike the Pacific coast region, where water power abounds and industry is relatively small, the superpower zone has relatively small hydroelectric resources and maximum industrial-power requirements. When the increases during the last 10 years are projected to 1930, even at a lower rate, the total energy requirement of the zone in that year is found to be 31,000,000,000 kilowatt-hours, of which about 21 per cent can be supplied from water power.

Fortunately some of the best coal deposits in the country lie near this great industrial territory, and a prime economic purpose should be so to conjoin the hydroelectric supply of power to the steam-electric supply as to produce a maximum of energy for a minimum investment of capital and a minimum operating expense, and at the same time to conserve the rapidly disappearing cheap fuels of the Appalachian coal fields.

The superpower system here recommended comprehends a plan of power production that includes the generation of electricity by steam at tidewater and on inland waters where a sufficient quantity of condensing water can be obtained, and also the utilization of all hydroelectric power that may be economically obtainable from rivers within the zone or within transmission distance of it. The electric power so generated will be coordinated through a system of interconnected transmission lines, the potentials of which will be on the order of 220,000 and 110,000 volts. (For the assignment of these voltages see Appendix E.)

Plates II and III show how the superpower system should appear in 1925 and 1930. They give the locations of the new steam-electric plants, the hydroelectric plants, and the load centers for each year and show the interconnecting network of transmission systems required. Had superpower been available in 1919 the number of load centers to which its power could have

been supplied economically would have been 20, and this number as the maps show, will increase to 34 in 1930.

Under the present independent operation of the electric utilities and the manufacturing industries in the superpower zone the existing power plants are numerous and small. The average capacity of the 558 electric-utility plants now in operation in the zone is 7,900 kilowatts, and that of the steam-electric plants 10,000 kilowatts, while the hydroelectric plants average only 2,800 kilowatts. Out of 96,000 industrial establishments in the superpower zone 76,000 use power, and each of these isolated plants averages about 350 horsepower. Under the superpower system, by contrast, the number of power stations required to supply the entire zone in 1930 will be only 273, of which 218 will belong to the existing electric utilities. The capacity of the base-load steam plants will range from 60,000 to 300,000 kilowatts. In none of these plants will there be installed a turbo generator having a capacity of less than 30,000 kilowatts.

The new power stations and load centers will be so located with reference to the existing electric-utility plants that are to be incorporated in the system as to insure the maximum aggregate economy in power generation and transmission. A prime object to be attained in the superpower plan is the maximum economic utilization of existing generation and transmission equipment. In the early stages, while the superpower system is taking form, existing electric-utility capacity will predominate. Indeed, in 1930, as much as 31 per cent of the total superpower capacity will be contained in plants belonging to the present electric-utility companies.

The superpower system would and should fail to achieve its purpose if it should seek to supplant or even to compete with the existing electric utilities. Its object is exactly the reverse. In view of the great economies already effected by the electric public utilities, the creation of the superpower system can be urged only as it shall come into being to coordinate and supplement these utilities and carry to a higher degree the service and the economies incident to their present operation.

It should not be difficult to see, therefore, that the superpower system will provide for a series of load centers, at which power may be made available at lower cost than can be attained under the present unassociated systems of power production and distribution. At these load centers, located where economy may dictate, power so made available will be coordinated with power generated at existing electric-utility plants and distributed by transmission or distribution systems to the consumers, as it is to-day.

Under the heading "Summary of conclusions" it was stated that in the operation of electric utilities the superpower system, in comparison with independent operation, would save $239,000,000 in 1930. The question might be asked, Could not the same result be attained by the electric utilities themselves in the course of their normal expansion? The coordinated plan of power production by the superpower system represents the highest possible commercial efficiency and must therefore yield the maximum economies. I believe that no possible expansion of the present uncoordinated electric public utilities can reach the economic results promised by the superpower system, for the physical structure of the superpower system, as outlined in the appendixes to this report, employs minimum capital and minimum labor to produce a maximum of electric energy.

In the discussion of the superpower system there has been some tendency to look upon it more as a company than as a principle, but the foregoing statements should make it clear that superpower is merely a name for the principles that should govern the expansion of the existing electric utilities. A better term than superpower would have been superutility.

The electric utilities, the railroads, and the industries within the superpower zone have freely given their data to permit a determination of the amount and location of load and demand and have supplemented them with data showing the cost of producing their power in 1919. The superpower system will be a regional system supplying power through the electric utilities, at the highest economy, to the two agencies that are most vital to American existence—industry and transportation. The highest economy in investment and operation will be gained by

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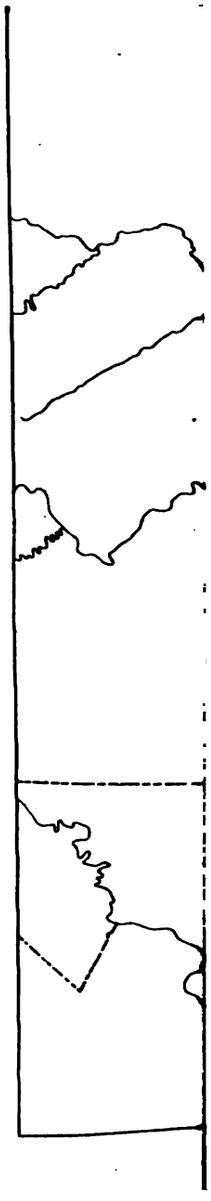

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maintaining the size of the electric generating units at a maximum and thus reducing capital and operating cost to a minimum. The highest economy resulting from diversity economy will be gained through a wisely ordered interconnecting system of lines of transmission and distribution—a system which also offers the highest economy in the development of water power, for it makes possible the use of a maximum number of cubic feet of water per square mile of drainage area, thus reducing to a minimum the amount of power generated by steam.

In determining the amount and cost of the power produced within the superpower zone it was obviously necessary to select the latest year for which full construction and operating information could be obtained—the year 1919. On account of the extremely high cost of material in that year, however, this selection has introduced high fixed charges; but this is offset by the saving in high-priced coal and the consequent reduction in operating expenses resulting from the higher efficiency of the superpower system as compared with the present independently operated electric utilities.

As efficiencies have increased with the enlargement of the plants operated, the cost of producing power has been lowered. The best reflection of this decrease in cost is seen in the electric utilities themselves. Much of it has been the result of interconnection, which has permitted the use of larger machinery and a better utilization of water power. In the isolated plants and on the railroads, however, although the cost of power has been lowered, the decrease has been far less, because in both of these the power equipment is small and its operation is affected by conditions that prevent much gain in efficiency.

It may be argued that it would be unfair to extend the costs of independent operation for 1919 to 1930 and at that year strike a difference between them and those of the superpower system. This argument can not be gainsaid, but if the figures representing the cost in 1919 of unassociated power production are not lowered by 1930 then the full savings previously indicated as possible by the superpower system can be claimed. Unquestionably the figures for 1919 will be lowered by the further consolidation of existing utilities, but unless the electric utilities act in complete cooperation and themselves adopt a plan of coordinated expansion by which the load centers of the zone can be supplied with power at minimum cost then the economies they can independently effect will never reach the maximum attainable under the superpower system, which involves the complete coordination of the existing power stations of the electric utilities and the new stations to be constructed.

DEFINITIONS.

A few of the terms used in this report are defined below:

Assigned locomotives.—Locomotives actually engaged in runs between terminals or in switching operations.

Base-load plant.—A generating plant designed to carry that part of the load which is practically continuous.

Capacity factor.—The average load on a plant expressed as a percentage of the effective capacity of the plant.

Class 1 railroads.—Railroads having an annual operating revenue of $1,000,000 or more.

Cost of power delivered.—The sum of the cost of production and transmission and the general expense.

Diversity economy.—The saving made by interconnecting generating stations whose peak loads are reached at different times and so distributing the load among stations of different unit operating costs as to deliver power at minimum cost.

Diversity factor.—The ratio of the sum of the maximum power demands of the subdivisions of any system or part of a system to the maximum demand of the whole system or of the part of the system under consideration, measured at the point of supply. (Standards of the American Institute of Electrical Engineers, section 3464.)

Effective capacity.—The rated capacity of a plant as limited by boilers, prime movers, or generators.

Fixed charges.—The cost of money, depreciation, obsolescence, taxes, and insurance.

General expenses.—The administrative, legal, and fixed expenses and expense of office supplies.

Load factor (hour yearly).—The ratio of the average power to the peak power expressed as a percentage of the peak power.

Operating cost.—The cost of fuel, operating labor, maintenance, (including depreciation and obsolescence) and supplies.

Peak-load plant.—A generating plant designed to carry the peak loads.

Production cost.—The sum of the operating cost and fixed charges for a power plant.

Reproduction cost.—The cost in midyear of 1919 of an up-to-date plant of the same capacity.

Total ton-miles.—The weight of the train in tons, including the locomotive and tender, multiplied by the distance run in miles.

Trailing ton-miles.—The total weight of the train in tons, exclusive of the locomotive and tender, multiplied by the distance run in miles.

Transmission system cost.—The sum of the operating cost and fixed charges for a transmission system, including substations.

SUMMARY OF APPENDIXES.

The problem set for the engineering staff, briefly stated, was that of determining the total amount and the location of the power load that would be required for municipal, private, industrial, and railroad purposes at a date sufficiently in advance to permit the construction of a system of the highest economy to supply it. The date chosen was 1930, and the allocation of the load and the power-generating facilities for the six geographic divisions of the superpower zone is shown in Appendix E.

In the earlier stages of the investigation, therefore, the entire attention of the engineering staff was concentrated upon the work of determining the amount and the location of the load. This work was done through the cooperation of the electric utilities, the railroads, and the industries within the zone. The engineering staff then undertook to determine the amount and the location of generating and transmission capacity to supply the demand thus ascertained.

The appendixes, which are here only briefly summarized, are largely, if not entirely, the work of their authors, to whom reference is made under "Organization," in Appendix A. I believe I can fairly say that in the endeavor to solve the problem set for us the engineering staff followed a route in which my principal engineering associates, Messrs. Butler, Flood, Hutchinson, and Imlay, were in full accord with me. To them and to their assistants may be ascribed the full credit for the collection of the information required for the report and a very large share of the credit for working it up. For the details that served as the groundwork for the conclusions reached I would suggest a careful study of the appendixes.

Appendix B. Electric utilities in independent operation in the superpower zone in 1919.

In the New York, Baltimore, and Washington load centers the predominating frequency is 25 cycles; in the remainder of the zone it is 60 cycles.

The electric-utility load will grow from approximately 10,000,000,000 kilowatt hours in 1919 to 26,000,000,000 kilowatt hours in 1930. The figure for 1930 has been predicated upon an annual rate of growth of 9 per cent, a safe figure, for the annual rate of growth during the last 10 years has been 11 per cent.

Figure 1 shows the distribution of electric-utility load between Boston and Washington by load centers for 1919 and indicates the tremendous concentration of power in the vicinity of New York City. The data given by the electric utilities concerning load growth are shown graphically in figure 21, which indicates the decentralization of power that will have taken place by 1930.

It is apparent that the locations for future electric-power plants must lie outside the densely populated districts. The high-voltage circuits of the superpower system in general will form ring busses around the larger cities of the zone, on the outskirts of which will be located substations with transformers having their primaries connected to the superpower circuits and their secondaries connected to the existing distribution lines of the electric utilities.

The peak loads for the Anthracite and Mohawk-Hudson divisions occur in the morning. The peaks for the other divisions occur in the afternoon. The annual peak for the zone as a whole occurs about 5 in the afternoon, usually in December.

Out of 558 electric-utility plants in the superpower zone there are but 36 whose capacity equals or exceeds the average capacity of the plants for the superpower system in 1930. Out of the 1,074 generating units of 500 kilowatts or more operating within the zone in 1919, only about 20 had a capacity greater than 30,000 kilowatts.

It is of interest to note that a plant delivering power with a load factor of 40 per cent turns out 76 per cent of its energy (kilowatt-hours) before its capacity (kilowatts) has

been taxed 40 per cent, the remaining 60 per cent of its capacity being required for the remaining 24 per cent of energy, thus showing the small amount of energy involved in peak operation. This statement brings out the very important point that the superpower system employs the generating capacity of the existing electric utilities for application to peak loads, the new and larger superpower stations contributing their low-cost energy for base load.

The relative cost of power production by large and small units is shown. A comparison of the production cost for plants greater than 100,000 kilowatts with that of those less than 1,000 kilowatts shows a ratio of 3 to 1 for cost of fuel and 4 to 1 for cost of maintenance and supplies in favor of the larger plants. With these marked economies in mind, it is clear that base load should be supplied from superpower plants employing units of not less than 30,000 kilowatts each.

Table 3 brings out the performance of 400 steam-electric plants and 158 hydroelectric plants operating within the superpower zone in 1919. The fuel rate for the average steam-power plant is 2.73 pounds per kilowatt-hour, with a heat requirement of 35,800 British thermal units per kilowatt-hour. These figures contrast strikingly with the fuel rate of 1.41 pounds per kilowatt-hour and the heat requirement of 18,300 British thermal units per kilowatt-hour that can be obtained from the base-load steam-electric plants of the superpower system operating at the same annual capacity factor.

Under independent operation in 1919 the generating capacity required was 46 per cent greater than the annual peak load, and the resulting annual capacity factor was 26 per cent; under the superpower system in 1930, through joint reserve, the generating capacity required will be only 9 per cent greater than the annual peak, and the annual capacity factor will be 45 per cent.

The reproduction cost for steam and hydroelectric plants under independent operation as of 1919 is $156 per kilowatt of capacity; the corresponding cost under superpower operation is $125 per kilowatt.

The average unit production cost for the electric utilities in 1919 was 1.93 cents per kilowatt-hour; the cost of the electric power produced by steam was 2.12 cents, and that of the hydroelectric power was 0.94 cent. In the steam-electric base-load plants for the superpower system the production cost, based upon the same capacity factor that is applied to electric independent operation, will be 0.99 cent per kilowatt hour, as compared with 2.12 cents.

Appendix C. Proposed electrification of heavy-traction railroads in the superpower zone.

Density of traffic is the controlling factor in railroad electrification. Within the superpower zone there is a large railroad mileage upon which the traffic is sufficiently dense to require careful consideration of the savings to be effected by electrification—in fuel, in maintenance of equipment, and through economies incident to the reduction in train-miles.

The zone contains some 36,000 miles of main line, yards, and sidings, of which 19,000 miles could be profitably electrified. The total capital expenditure necessary to electrify this mileage is $570,000,000, and the result of the analysis promises an annual saving of $81,000,000, or 14.2 per cent on the investment.

The response by the railroads to requests for data relating to their operations in 1919 has been so generous and the compilation of these data in this appendix, with the conclusions deduced from them, is so complete that instead of attempting to summarize the appendix I will only refer to the more general aspects of the problem.

In the earlier days of railroad electrification, as, for example, on the New York Central, the New Haven, and the Pennsylvania, we were all groping and feeling our way. That was 20 years ago, and in this age of rapid progress 20 years is a long time in which to make up our minds regarding the fundamental principles of electrification. Even the dyed-in-the-wool steam-locomotive man has become interested in the electric locomotive, because he has found that the steam locomotive can not perform its work satisfactorily in the environment that belongs to the electric locomotive. The reverse is also true—there are railroad tracks on which

electric locomotives have no place. To find where electric train propulsion should be used does not, however, completely solve the problem. Money must be obtained to put electric locomotives where they belong.

When the electrified portions of the New York Central, the New Haven, and the Pennsylvania were first operated the railroad companies paid out their own dollars for their motive-power equipment and for the power stations to run it. The whole expenditure was therefore borne by the railroads. About that time Mr. Samuel Insull, with far-seeing perspective, declared that the power required for electrified railroads should come from the large electric-utility plants. I am glad to admit that I was wrong when with others I disagreed with him. I am more glad, however, to say that I stayed wrong only long enough to make up my mind to be a party to a contract for 40,000,000 kilowatt-hours per annum from the United Electric Light & Power Co. to supply the west end of the electrified stretch of the New Haven road. Since that date it has been my belief that the production of electric energy should be confined to those in the power business and that the railroads should purchase electric energy and confine themselves to the transportation business. The railroads will thus be assured of adequate, reliable, and cheaper power and will be relieved of the cost of building their own power stations.

A further step of fundamental importance that would lighten still more the burden of investment cost, which at this time the railroads are so peculiarly unfitted to carry, would be to standardize as far as possible the motive-power equipment required for the three classes of railroad service—passenger, freight, and switching. Such standardization would simplify electrification and therefore reduce the cost of maintaining equipment, as well as lessen the investment cost. Motive-power equipment so standardized as to be operative on 19,000 miles of track would offer a foundation for an equipment trust bond that would be most attractive to bankers and would relieve the railroads of a heavy capital requirement. In short, the railroads, not being called upon to build motive-power equipment or power stations, would have to pay only the electrification cost incident to their contact and distribution lines, and the charge against their capital account would be only 20 to 25 per cent of the amount required 20 years ago, when they were paying 100 per cent of the cost of electrification.

I hold no brief in this report with regard to systems. It has been well said that either the direct-current or the alternating-current system is better than steam. After these 20 years of heavy-railroad electrification one can not close his eyes to the advantages or disadvantages of either system. Though I was instrumental in selecting and installing the single-phase (alternating current) system on the New York, New Haven & Hartford Railroad, I am conscious of two elements that may militate against this system—(1) the low power factor, which calls for unproductive capacity in power-plant and transmission equipment, and (2) the undeniable fact that this system induces serious electromagnetic effects upon adjacent telegraph and telephone facilities. In the high-voltage direct-current system electromagnetic induction is practically eliminated, but that system has not yet offered a practical multiple-control unit equipment such as is necessary to suburban operation. On the other hand, the multiple-unit equipment of the high-voltage single-phase system has given the highest satisfaction on the railroads that use it. But these are mere details. The best high-voltage direct-current multiple-unit equipment must be worked out if the railroads in this zone are to be so operated. If power is obtained from substations of electric-utility companies the investment cost will be practically the same for either of the two systems.

This explanation should make it clear that neither system is here favored as against the other, notwithstanding the fact that in Appendix C the 3,000-volt direct-current system has been employed in making the estimates of construction cost. This has been done only in order that a complete system of construction figures could be worked out, from the superpower stations to the driving wheels of the motive power.

Although the zone is large enough to permit the use of both systems, I would emphasize the recommendation that the great electric manufacturing companies of this country draw

together rather than apart and that they unite in a common specification for electric motive power to replace steam, for the final result would be tremendously improved by this action.

In addition to the argument that the railroad companies should buy power from the electric utilities because the utilities are in the business of producing power, there is the very excellent argument that the railroad load will not only swell the output of the utilities and therefore permit the installation of larger and more economical generating units but will produce the inherently high load factor common to railroad operation and thus tend to promote the maximum use of the generating capacity installed.

In contrast with the indicated return of 33 per cent to the electric utilities and the industries through the operation of the superpower system the average return to the railroads on the investment necessary to electrify 19,000 miles will be only 14.2 per cent. Of course the percentage of return will vary from division to division, and figure 15 (p. 77) shows that this variation will be from 11 to 19 per cent. Naturally, therefore, the selection of railroad properties to be electrified, aside from requirements for pure increase in capacity, will be governed by the percentage of return to be expected. The greater savings attainable by the utilities and the industries should not overshadow the urgent requirement of railroad electrification. As measured to-day a money return of 14.2 per cent is good, and I think it can be fairly said that we must now begin to live into the new form of train propulsion that is offered by electricity, for thus will be created a means of railroad expansion to support the coming American industrial expansion, which our resources and the world requirements can not possibly fail to induce within the near future. No one can deny that the system in which we must live should carry with it prime principles of economy, which will include these features of commercial efficiency. Any saving in the consumption of coal by the railroads means the transfer of cars from wasteful to productive transportation.

The normal amount demanded annually for extensions and betterments for the railroads within the superpower zone is approximately $150,000,000, an amount which even in the face of present construction prices would suffice in three or four years to cover the cost of electrifying all the mileage mentioned. Should we continue to tinker with an old and inefficient machine when it is impossible to escape the installation of the modern and efficient one?

The higher price of coal and labor of the future compared with pre-war prices, which has dislocated the economic balance between railroad grades and the tractive power of locomotives; the lack of sufficient motive power that has been plainly demonstrated at critical periods in recent years; the steady increase in the tractive capacity of individual locomotives noted during the last 20 years; and the present hauling of trains weighing two to three times as much as those of the recent past are plain indications that in the near future large sums of money must be expended for motive power.

The well-known characteristics of electric locomotives, whose capacity and speed are not limited by rail and bridge strength and tunnel clearance, make electrification the true system into which we must promptly grow or pay the price for delay. This aspect is one entirely apart from that of the returns to be expected on the proposed capital investment shown in this report.

Appendix D. Industry in the superpower zone.

The maximum economical use of purchased power in the superpower zone in 1919 would have produced a saving in coal amounting to 13,502,100 tons. To determine this saving it was necessary to acertain the coal-burning rates of the industries that developed their own power as against the rates that would have been required to supply them power from central stations.

Out of 96,000 individual establishments in the zone 76,000 used power. The industries analyzed included manufacturing establishments, laundries, mines and quarries, and Government manufacturing institutions. In Table 48 the industries are listed under 17 main groups, which are so subdivided as to form 53 classes.

The fundamental information required for the determination of the mechanical power-supply equipment and fuel used by all the industries necessarily had to be procured from the Bureau of the Census, if for no other reason because time would not have permitted its independent compilation. This information is presented in the tables of the appendix variously—by character of power supply, by industrial subgroups, by county, and by size of plant. The presentation of the data in this form appears not only to be essential to this analysis but should be of great interest and value to all engineers who are interested in industrial power and heat.

The analysis showed that in 1919 the equivalent of 9,311,440,000 kilowatt-hours was developed by prime movers operated by the industries themselves and that 3,338,800,000 kilowatt-hours was purchased. It further shows that it would have been economical to shut down 4,008,200 horsepower of prime movers and purchase energy to the amount of 5,623,800,000 kilowatt-hours, which would have made a total of 8,962,600,000 kilowatt-hours purchased in 1919. The saving in coal thus effected would have been 13,502,100 tons—71 per cent of the coal used by the industries for producing power, or 25 per cent of all the coal used by the industries. In making the industrial power analysis care has been taken not to invade the field of what might be termed by-product power—that is, power produced by the industries from coal that would have been burned anyway for heat and in industrial processes. The saving determined is that made on coal burned for power and chargeable to the supply of power. It has been difficult to separate one class of coal burning from the other, yet after consultation with many authorities a separation has been made..

In general it has been found that industrial establishments which require 500 horsepower or less can economically purchase energy. Only those that need more than 500 horsepower and that have special requirements for heat can generate their own power economically, and even these should have central-station connections to take up irregularities of load. The efficiency of power production by isolated industrial plants is precluded from any considerable improvement by their necessarily small average capacity.

A careful study of the power requirement for industrial establishments in the superpower zone has been made and has shown that by 1930 an annual saving of $190,000,000 can be made to the industries themselves above the fixed charges against an investment of $185,000,000 for the motor equipment necessary to utilize the power.

Such a result will not of course be effected by any mysterious magical act of a superpower system. Indeed, many of the electric utilities have already been in a position to offer large savings to the industrial plants within reach of their distribution circuits.

In this study of the economical generation and distribution of power throughout the superpower zone full allowance has been made for the capital required to place regional plants in action, with their generating and transmission equipment connected with the distribution systems of the existing electric utilities, so as to reach every industrial worker in the zone. It is therefore hoped that this presentation of the saving that can be made may prove worthy of consideration by the executive officials of the industrial establishments in the zone.

Appendix E. Performance and cost of the superpower system.

Appendix E summarizes the report. It is built up of the appendixes that precede and follow it. It gives the investment cost and the cost of power delivered to the load centers for 1919, 1925, and 1930.

The cost of power at the busses of the electric utilities includes a return of 10 per cent on the money invested in the generating and transmission system. It is thought that during this present period of high interest a yield of not less than 10 per cent would be required to attract the necessary capital to this form of investment.

Figure 1 shows the distribution of load in the superpower zone in 1919. A comparison of this diagram with figures 20 and 21 brings out the degree of decentralization that is possible through the agency of a superpower system. The 20 load centers of 1919 are increased to 34 by 1930, and the superpower transmission system can not economically be tapped for a load of less than 20,000 kilowatts.

The frequency selected for the superpower system is 60 cycles. At the New York, Baltimore, and Washington load centers the principal frequency is 25 cycles, but generator sales in the ratio of 9 to 6½ in favor of 60-cycle apparatus during the last 5 years and generated output in the ratio of 4.75 to 2.2 during the last 10 years unquestionably establish the trend and determine the choice for the superpower system.

The regional diversity existing in the superpower zone is assumed to be of more theoretical than practical importance, except the diversity existing between the Anthracite, Metropolitan, and Southern divisions, which will become very marked with the growth of the Anthracite division load by 1925 and 1930.

Capacity to provide for load growth has been determined largely from the trend of the load factor. (See pp. 154–156.) The load factor for the electric utilities within the zone increased from 34 per cent in 1910 to 39 per cent in 1919. In some of the geographic divisions, such as the Metropolitan, the increase in load factor has been very slight; in others it has been large—for example, in the Southern division the load factor has increased from 33 to 43 per cent, largely owing to additions of industrial load.

In 1919 only 15 per cent of the total output of the electric utilities was hydroelectric power. By 1930 this proportion will have been increased to 21 per cent. In 1925 50 per cent of the total generating capacity for superpower operation will be contained in plants owned by the present electric utilities, and they will produce about 26 per cent of the energy. By 1930 the corresponding percentage of generating capacity will have dropped to 39 per cent, and these plants will furnish only 18 per cent of the total output. They will be used principally to carry peak load.

In 1919 the average size of the electric-utility plants within the zone was 7,900 kilowatts; by 1930 this size will be increased to 29,900 kilowatts. An even more marked contrast is that between the average size of new steam-electric plants to be installed, which is 218,000 kilowatts, and the average size of the steam-electric utility plants existing in 1919, which is 10,000 kilowatts.

Of far-reaching importance, in my opinion, will be the maximum use of diversity economy made possible by the interconnecting circuits of the superpower system. By diversity economy I mean the ability to select capacity that will produce power at minimum cost.

The unit investment cost in new power plants for the superpower system is $118.25 per kilowatt of effective capacity; that for all plants is $125 per kilowatt. The unit reproduction cost of the electric utilities in 1919 was $156 per kilowatt of effective capacity. This reduction in cost for the superpower system is due to the greatly increased size of the plants. The contrast is even more striking in the unit investment cost per kilowatt of demand, which is $196 per kilowatt for independent operation and only $136 per kilowatt for the superpower system.

In 1930 the transmission system of the superpower system will represent 9.3 per cent of the total investment cost.

The new money required for the superpower system up to 1925 is $453,143,000 and up to 1930 $693,218,000, thus making it necessary to raise $90,600,000 annually for the first five years and $48,000,000 annually for the following five years. The early installation of a transmission network calls for the higher rate for the first five years. This rate, however, is justified by the annual saving resulting from interconnection.

If the demand of 1930 were provided for by the independent systems as constructed to-day the total sum required would be $856,000,000, or $85,600,000 a year. Accordingly the construction of the superpower system will involve a saving in investment cost of $163,000,000 during the next 10 years; in other words, the increase of capacity to meet growing demands can be financed by the superpower plan for $16,300,000 annually less than by the normal expansion of the existing electric utilities. On page 169 a full comparison is made between independent operation and superpower operation for the years 1919, 1925, and 1930. The net annual saving by 1930 above fixed charges and capital is approximately $239,000,000.

Of great interest is the economic relation established between the joint use of steam and water power. It is shown that steam and water power can be so combined as to yield annually

$69,550,000 on an increased investment of only $44,838,000. Here is exemplified one of the prime advantages of superpower production, costs being reduced by means of the interconnecting system which permits the highest economy in steam-produced power together with the maximum use of water power.

The load growth in the Eastern New England, Western New England, and Mohawk-Hudson divisions should be sufficient to absorb the total available output of the St. Lawrence project by 1932; and the growth in the Metropolitan division should be sufficient to absorb 300,000 kilowatts at a load factor of 80 per cent from Niagara in the same year. Power could doubtless be purchased from these hydroelectric plants at not over $20 per horsepower-year delivered at their bus bars, and accordingly this figure is used in determining the effect of this arrangement on the cost of power to the divisions of the superpower zone that would be so supplied.

The total annual cost for power delivered in 1932 to the load centers of the Eastern New England, Western New England, and Mohawk-Hudson divisions, if St. Lawrence power is used, will be $130,273,000; if the excess energy required in 1932 over that of 1930 were furnished by new steam-electric plants the cost would be about $141,601,000. The development of St. Lawrence River would therefore save $11,328,000 a year to these geographic divisions; moreover, the total investment required to utilize purchased St. Lawrence power would be $24,826,000 less than that required to construct new steam-electric plants to supply this excess energy. In the three divisions mentioned, which lie farthest from the coal fields, the cost of power generated by steam plants is inherently high, and therefore the St. Lawrence development will be of very great benefit to them.

The total cost to the Metropolitan division for the power it will require in 1932, if Niagara power is used, will be $107,651,000. If the growth in energy required between 1930 and 1932 were supplied from new steam-electric plants in the Metropolitan division, the total cost in 1932 would be $110,899,000, showing an annual saving of $3,248,000 in favor of Niagara power. Were the power purchased from the Niagara power interests, the total investment for 1932 would be $5,080,000 less than that required to generate an equal amount by steam.

The use of the St. Lawrence power as suggested above would save 2,234,000 tons of coal annually, and the use of Niagara power in the Metropolitan division as suggested would save 1,204,000 tons of coal annually.

The new power-plant capacity required in the superpower zone would be 3,098,000 kilowatts in 1925 and 4,980,000 kilowatts in 1930.

In Table 76 is shown the cost of power delivered from the new power plants and transmission system of the superpower system for 1930. The lowest rate is that for the Southern division, 6.8 mills per kilowatt-hour; the highest is that for Western New England, 11.4 mills. The average for the whole superpower zone is 8.4 mills. This, however, is the combined rate for power generated in new, large, and highly efficient hydroelectric and steam plants. The true comparison in production costs between the superpower system as of 1930 and independent operation for 1919 is 9.3 mills per kilowatt-hour as against 19.3 mills per kilowatt-hour.

Finally, the appendix shows that in 1930 the cost of the power produced by the superpower system, *inclusive* of fixed charges, as delivered on the busses of the electric utilities, would be 10.6 mills per kilowatt-hour, whereas the cost under independent operation as of 1919, *exclusive* of fixed charges, would be practically the same. This, in my opinion, is the fundamental reason why the expansion of electric utilities should follow the superpower plan.

Appendix F. Steam-electric plants for the superpower system.

Appendix F shows the capacity of the existing plants of the electric utilities to be retained in the superpower system and their location by geographic divisions. The total capacity retained is 2,677,000 kilowatts, which represents 79 per cent of the effective capacity of the steam-electric public utilities in the superpower zone in 1919. The reproduction cost of these plants is $329,219,000.

This appendix presents curves showing the average performance of existing steam plants and of the plants in the superpower system. The character and the design of the base-load steam plants are discussed. The performance of the retained steam plants shows that these should average about 2.15 pounds of coal per kilowatt-hour, as against 2.73 pounds per kilowatt-hour for all electric-utility steam plants operating in the zone in 1919, when both groups are operating at the same annual capacity factor.

The average size of the steam plants retained is 44,600 kilowatts, and the reproduction cost as of 1919 is $124 per kilowatt, as against $109.50 for new steam plants as of 1930. After consultation with many representatives of manufacturers in all parts of the country and with designing and operating engineers, the following operating characteristics for base-load steam plants were determined:

Steam pressure at turbine throttle, 300 pounds per square inch.
Superheat at turbine throttle, 230° F.
Final temperature at turbine throttle, 652° F.
Absolute pressure at turbine exhaust nozzle, 1 inch of mercury.

Of special interest is Table 80, showing summarized estimates of cost for three sizes of base-load steam plants. These estimates were made after consultation with many of the best authorities in power-station design and are considered conservative.

The base-load steam plants for the system will be composed of units of 30,000 kilowatts or multiples thereof, and the largest plant proposed is one of 360,000 kilowatts. These plants will be built in units, and some of them will require the full 10 years for their expansion to complete size. Plate VIII shows the performance for these plants and takes into account such reasonable advances in the art of power production as may be made in 10 years. By 1930 the new steam-electric plants should operate at a capacity factor of about 62 per cent with a fuel rate of 1.43 pounds of coal per kilowatt-hour.

Table 80 shows that the unit investment cost of a base-load steam-electric plant varies but little with size after 120,000 kilowatts has been reached, being only 6.5 per cent less for a 360,000-kilowatt station than for a 120,000-kilowatt station. On the other hand, the unit cost of a 30,000-kilowatt plant is 23 per cent more than that of a 120,000-kilowatt plant.

The proposed new steam-electric plants have been so located as to obtain the fullest advantage of low freight rates, easy coal-delivery routes, and ample condensing water. Fourteen new steam-electric plants, aggregating 2,520,000 kilowatts, will be required by 1925, and four additional plants, or eighteen in all, aggregating 3,930,000 kilowatts, by 1930. The total for 1925 is equivalent to 63 per cent of all the present steam-electric generating capacity in service for the utilities, and that for 1930 to 98 per cent.

In the Anthracite division base-load steam-electric plants, using buckwheat No. 3 coal, can be operated most advantageously because of the combined use of their power for the Metropolitan and Southern divisions. The diversity between these divisions and the Anthracite division will permit operation at a capacity factor of 75 per cent, and under these conditions electric energy can be produced in 1930, inclusive of fixed charges, at 5.7 mills per kilowatt-hour. This figure is sufficiently low to permit the additional fixed charges on transmission for the part of the power that is sent to the tidewater region.

There are three steam-electric power-station sites in the Anthracite region—one near Pittston, one near the mouth of Nescopeck Creek, and one near Sunbury, all in Pennsylvania and all on Susquehanna River—at which sufficient condensing water is available to permit the development of 300,000 kilowatts each.

Appendix G. Hydroelectric plants for the superpower system.

The construction of a hydroelectric plant is economically justified if it produces its power at a cost less than that of a steam-electric plant of the same capacity. With maximum development of water power, however, the hydroelectric energy available within the superpower zone will amount to less than 21 per cent of the total electric power required in 1930.

Of especial importance in determining the location and capacity of the new water-power plants for the zone is the economy attained by the development of rivers beyond their primary power. The dam and headworks of a hydroelectric plant are the principal items of its cost. Additional generating units can be installed at half the cost of providing the same steam-electric capacity, and the construction of storage reservoirs will increase the capacity of the plant above the primary power of the river for effective use under peak loads.

The principal rivers which can contribute water power to the superpower zone are the Potomac, Susquehanna, Delaware, Hudson, and Connecticut. It is proposed to utilize power from these rivers in 1930 to the following extent:

River.	Capacity (kilowatts).	Output (millions of kilowatt-hours).	Investment.	Production cost (mills per kilowatt-hour).
Potomac	200,000	950	$22,000,000	3.36
Susquehanna	185,000	1,230	28,000,000	3.22
Delaware	350,000	1,250	51,500,000	5.95
Hudson	150,000	900	38,350,000	5.84
Connecticut	165,000	760	29,000.000	5.45

It is proposed to develop these rivers above their primary power capacity for peak-load operation.

The water powers of Niagara and St. Lawrence rivers are within transmission distance of the superpower zone, but on account of the time required for construction on the St. Lawrence and of the treaty restrictions concerning the use of the water at Niagara Falls the power from these sources has not been considered available in the zone prior to 1930.

Under present construction and operating costs power purchased at Niagara or on St. Lawrence River at $20 a horsepower, ready for transmission at those points at potentials of not less than 220,000 volts, can be placed at Utica and Schenectady, N. Y., and at Northampton, Mass., for 4.6 mills per kilowatt-hour, and at Paterson, N. J., for 5.7 mills. These figures assume purchases of not less than 300,000 kilowatts delivered at a load factor of not less than 80 per cent.

The reproduction cost of the 451,500 kilowatts of existing hydroelectric capacity within the zone is $87,127,000. The new hydroelectric capacity which should be installed by 1930 will bring the total capacity up to 1,501,500 kilowatts, of which the old plants will represent 30 per cent. In 1930 the total hydroelectric investment will be $245,977,000, of which the old plants will represent 35 per cent.

Appendix H. The superpower transmission system.

So far as the existing electric utilities are concerned the superpower system begins and ends at their power-station busses, and so far as the new superpower plants are concerned it begins at these plants and ends on the busses of the existing electric utilities.

In presentations of the superpower plan I have said, "The primaries of to-day will be the secondaries of to-morrow." The existing transmission systems of the electric-utility companies, which comprise about 1,200 miles operated at 33,000 volts or higher, will become distribution rather than transmission systems, and they will of necessity require expansion to distribute the additional power delivered to them from the superpower system. The transmission features of the superpower system will therefore have to do only with the transmission of power from the new plants to load centers and to the busses of the existing electric-utility plants.

In 1930 the superpower transmission system should consist of 970 circuit miles of 220,000-volt lines and 4,696 circuit miles of 110,000-volt interconnecting lines. To these lines will be connected 5,600,000 kilovolt-amperes of transformer capacity, not including the transformer capacity in the base-load steam-electric plants. The construction of the transmission systems for the St. Lawrence and Niagara developments will add 3,140 circuit miles of 220,000-volt lines

and 1,824,000 kilovolt-amperes of transformers. Thus potentials of not less than 220,000 volts will be selected to transmit power from plants that are at considerable distances from the general interconnected superpower plants, and within the zone a potential of not less than 110,000 volts will be employed for interconnection between power and load centers. Plates II and III illustrate the proposed transmission arrangements.

In our study of the transmission problem within and without the superpower zone we have been most fortunate in obtaining advice and counsel from most of the high-tension experts of this country. Throughout this study it has been assumed as a necessary condition that the factor of reliability of transmission service for the superpower system must be the same as that of the busses of the power stations themselves. The transmission system has therefore been considered merely as a high-tension extension of those busses.

Appendix I. Reliability of service.

The inherent features of the superpower system themselves constitute adequate provision for reserves throughout its structure.

Appendix J. The relation of coal and coal-delivery routes to the superpower system.

The elements of greatest importance in insuring a continuous supply of power are coal and the routes by which coal is delivered to the superpower stations. Table 97 shows the distribution and use of coal in the superpower zone in 1919.

Plate X shows the available coal-mining districts and the principal rail routes to the proposed base-load steam-electric plants for 1930. This map relates especially to bituminous coal, for the plants that burn anthracite will be built in the anthracite region.

Throughout the study the cost of bituminous coal at the mines has been taken at $2.90 per short ton—the weighted average cost for 1919 to the industries that used bituminous coal. Doubtless labor costs will be reduced, but this reduction will be offset by the necessity of developing deeper mines and thinner seams and of extending underground haulage. The freight rates for 1919 were used in the calculations made for that year, but in the calculations for 1925 and 1930 the freight rates in force January 1, 1921, have been used.

For buckwheat coal used at stations in the anthracite region $1.75 per long ton has been used as the mine price for all periods, with $1 per long ton as the gathering charge.

The cost of coal delivered to the several load centers is shown in Table 98. Naturally these costs have played an important part in determining the location of steam-electric power stations.

Six months' storage capacity for each plant is recommended and would yield obvious advantages. It would absolutely prevent interruption of service due to lack of fuel; it would permit the purchase of coal at the lowest price; and it would help to stabilize the mining and transportation industries by making the demand for coal more uniform.

The question whether the superpower system should own coal mines, coal cars, coal-delivery routes, either or all, has been considered, and it has been concluded that the superpower system should confine its activities to the production of power and the storage of coal.

Appendix K. Use of process fuels and pulverized coal for base-load steam-electric plants.

Under present conditions, in general, coal must be used in raw form to produce cheap power. Coal is treated by certain processes for two purposes—to place its energy in more desirable form and to recover valuable by-products. If power is produced by the use of either coke or gas from process-fuel plants the value of the remaining products, when credited to the cost of such fuels, is not sufficient to reduce their cost below that of raw coal. As certain by-products are essential in time of war regardless of cost, however, it has been deemed desirable in selecting a site for a superpower station to provide space for a processing plant and to adopt a method of boiler-room construction that will permit the use of process fuel if and when its use is found desirable.

Appendix K compares the results of the use at base-load steam-electric plants of process fuels prepared by four methods. Table 99 shows that the cost of fuel prepared by three of the

four processes is higher than that of raw coal. Where gas is the process fuel made at by-product coke ovens it is cheaper than raw coal, but the large quantity of coke produced and the difficulty of disposing of it make this process generally impracticable. In certain situations, however, as the appendix points out, if the gas can be sold at a sufficiently high price processing of fuel may be economical.

The greatest promise regarding process fuel lies in the direction of devising plants that will convert raw fuel entirely into gas for consumption under the boilers at steam-electric stations and thus eliminate the enormous concentration of coke. Such a process plant used in combination with a steam-electric plant may produce fuel at a cost materially lower than that of raw coal, but the experimental work done is not yet sufficient to permit a stronger statement than that the progress made is exceedingly encouraging.

Appendix L. Basic costs.

Appendix L, which considers cost of money, depreciation and obsolescence, and taxes and insurance, is so brief that it is in itself a summary. The term "general expense," used in the estimates of cost of power production, includes salaries and expenses of administrative officers, engineers, and legal counsel, salaries of clerks, and expenses covering claims, stationery, printing, etc. Amortization, taxes, and insurance have been included under "fixed charges" rather than in this item.

Figure 61 shows the relation of "general expense" to annual gross revenue. This curve shows the small rate of percentage increase in charge for general expense for revenue above $3,000,000 and the marked increase for revenue less than $3,000,000.

APPENDIX A.

ORGANIZATION.

By W. S. Murray.

In planning this investigation and effecting its organization it was clear that the power market to be served by the proposed superpower system would be divided between the electric utilities, the railroads, and the isolated industrial establishments. Accordingly, Mr. Lorin E. Imlay, Dr. Cary T. Hutchinson, and Mr. Henry W. Butler were recommended and appointed, respectively, as division engineers in charge of the departments of power and transmission, of railroads, and of industries.

Associated with the division engineers as assistants, with duties so shifted as to maintain the highest engineering load factor in the work, were Messrs. Harold Goodwin, jr., Malcolm MacLaren, Norman C. McPherson, E. M. Newlin, B. J. Peterson, T. B. Rutherford, Arthur R. Wellwood, and Lyle A. Whitsit. I desire to make special mention of the able services rendered by these men.

Mr. N. C. Grover, chief hydraulic engineer of the United States Geological Survey, and Mr. O. P. Hood, chief mechanical engineer of the United States Bureau of Mines, were detailed for advisory service on the engineering staff. Mr. Grover, in addition to serving in his capacity as hydraulic engineer, rendered much assistance in administrative work, and Mr. Hood especially studied the problems pertaining to the use of process fuels.

That the work in all departments might be completely coordinated a principal assistant, charged with the assembling of all data and the preliminary preparation of the text of the report, was imperatively needed, and for this responsible duty Mr. Henry Flood, jr., was appointed, with the title of engineer-secretary. The duty of the engineer-secretary included the checking and coordination of the information collected for the several appendixes, and the speed of its collection or compilation for any particular appendix was increased or slackened, as occasion might require, to make it fit in with the rest, so that the report as a whole could be completed on time.

An advisory board was selected, consisting of the following members:

Lester P. Breckenridge (chairman), professor of mechanical engineering, Yale University, New Haven, Conn.; representing fuel engineering.

Magnus W. Alexander, managing director, National Industrial Conference Board, Boston, Mass.; representing National Industrial Conference Board.

Edward G. Buckland, vice president New York, New Haven & Hartford Railroad Co., New Haven, Conn.; representing New England railroads.

Charles L. Edgar, president Edison Electric Illuminating Co. of Boston, Boston, Mass.; representing National Electric Light Association.

Abraham T. Hardin, vice president New York Central Railroad Co., New York City; representing New York railroads.

Herbert Hoover, now Secretary of Commerce, Washington, D. C.; when appointed, president American Institute of Mining and Metallurgical Engineers; representing the mining industry.

William Kelly, Colonel, United States Army, Washington, D. C.; representing the War Department.

Elisha Lee, vice president Pennsylvania Railroad Co., Philadelphia, Pa.; representing railroads south of New York.

Arthur D. Little, president of Arthur D. Little, Inc., Cambridge, Mass.; representing electro-chemical and by-products industries.

James H. McGraw, president McGraw-Hill Co., Inc., New York City; representing the technical press.

John H. Pardee, president J. G. White Management Corporation, New York City; representing American Electric Railway Association.

Henry C. Perkins, mining engineer, Washington, D. C.; representing the mining industry.

Matthew S. Sloan, president Brooklyn Edison Co., Brooklyn, N. Y.; representing National Electric Light Association.

During the year eight meetings of the advisory board were held, and for the counsel and advice offered by its members I now express my most sincere appreciation.

Prof. L. P. Breckinridge, chairman of the advisory board, who has been constant in attendance at the meetings of the board and at many of the meetings of the engineering staff, has been encouragement personified and with his circumspection and his ability as a leader in the solution of the fuel problem has been of invaluable assistance.

I believe I can say without contradiction that the engineering staff is a unit in the findings of this report, and I can find no words to express fitly the tribute I owe these men for their loyalty and their able assistance.

The engineering staff, for all the members of which I speak, are especially grateful to the experts mentioned in the following list. To them apparently came the sense of responsibility of contributing their experience to the fullest where it was required. They made it apparent to me that I could call on them exhaustively, for they realized the national importance of this problem. Many, therefore, have been the consultations held with them, and their advice is reflected in the pages of this report.

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Sidney Withington, New York, New Haven & Hartford Railroad Co., New Haven, Conn.

A host of others, engineers and business men, contributed most valuable and pertinent information to this work, and I wish to make here the most grateful recognition of their services. The names of these coworkers follow, classified as to the nature of the information furnished:

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Rudolph Kudlich, Bureau of Mines, Washington, D. C.
C. E. Lesher, editor of Coal Age, New York City.
H. M. Matthews, coal-traffic manager, Baltimore & Ohio Railroad Co., Baltimore, Md.
R. J. Montgomery, vice president, Philadelphia & Reading Coal & Iron Co., Philadelphia, Pa.
E. W. Parker, Anthracite Bureau of Information, Philadelphia, Pa.
Henry M. Payne, consulting engineer, New York City.
F. B. Pryor, Consolidated Coal Co., Fairmont, W. Va.
George S. Rice, chief mining engineer, Bureau of Mines, Washington, D. C.
W. J. Richards, president, Philadelphia & Reading Coal &.Iron Co., Philadelphia, Pa.
J. S. Sillyman, mining engineer, Altoona, Pa.
G. N. Snider, coal-traffic manager, New York Central Railroad Co., New York City.
F. T. Snyder, Gas Producer Products (Inc.), New York City.
W. W. Taylor, acting vice president, International Coal Product Corporation, New York City.
Samuel A. Taylor, consulting engineer, Pittsburgh, Pa.
F. G. Tryon, United States Geological Survey, Washington, D. C.

Heavy traction.

Prof. W. J. Cunningham, School of Transportation, Harvard University, Cambridge, Mass.
J. H. Davis, electrical engineer, Baltimore & Ohio Railroad Co., Baltimore, Md.
F. B. Freeman, chief engineer, Boston & Albany Railroad Co., Boston, Mass.
A. W. Gibbs, chief mechanical engineer, Pennsylvania System, Philadelphia, Pa.
George Gibbs, consulting engineer, New York.
Edwin B. Katte, director electric traction, New York Central Railroad Co., New York City.
M. W. Manz, development engineer, Ohio Brass Co., Barberton, Ohio.
C. H. Quinn, electrical engineer, Norfolk & Western Railway Co., Roanoke, Va.
J. T. Wallis, chief of motive power, Pennsylvania System, Altoona, Pa.

Law and finance.

H. M. Addinsell, Harris Forbes & Co., New York.
A. E. Barrows, president, Narragansett Lighting Co., Providence, R. I.
T. R. Beal, president, Central Hudson Gas & Electric Co., Poughkeepsie, N. Y.
A. W. Burchard, vice president, General Electric Co., New York.
Frederick Darlington, Westinghouse Electric & Manufacturing Co., New York.

F. M. Feiker, Assistant to the Secretary of Commerce, Washington, D. C.
H. I. Harriman, president, New England Power Co., Boston, Mass.
John Price Jackson, Ardmore, Pa.
John W. Lieb, vice president, New York Edison Co., New York.
Joseph B. McCall, president, Philadelphia Electric Co., Philadelphia, Pa.
Thomas M. McCarter, president, Public Service Electric Co., Newark, N. J.
D. E. Manson, vice president, Charles H. Tenney & Co., Boston, Mass.
S. Z. Mitchell, president, Electric Bond & Share Co., New York.
Thomas E. Murray, president, Thomas E. Murray (Inc.), New York.
E. W. Rice, president, General Electric Co., New York.
James Sheldon, Lee Higginson & Co., New York.
Guy E. Tripp, chairman board of directors, Westinghouse Electric & Manufacturing Co., New York.
Herbert Wagner, president, Consolidated Gas, Electric Light & Power Co., Baltimore, Md.
O. D. Young, vice president, General Electric Co., New York.

An appropriation of $250,000 was requested to cover the investigation and report. Congress appropriated $125,000, with the proviso that additional funds could be subscribed by the parties in interest. The electric utilities, industries, and railroads rendered so much valuable engineering assistance that the additional amount required to complete the investigation and report was only $26,000. This amount was subscribed by the electric public utilities and manufacturers within the zone, and its welcome receipt is now gratefully acknowledged. The sum of $25,000 of the Federal appropriation was expended "for a survey of power production and distribution in the United States" in accordance with the terms of the appropriating act.

In concluding this investigation I wish to say that when I was asked by the Secretary of the Interior to accept the chairmanship of the superpower survey I did so with the predominating thought that a large responsibility would be attached to the authorship of the report to be prepared, and that in this great work no one man should assume that responsibility. Nothing can so surely bring success to an enterprise of this kind as its prosecution under the concordant action of a large number of minds. The estimate of the saving to be effected by the superpower system in 1930 is based upon the cost of power production in 1919, and we have no doubt that it can be made. We also agree that much of this saving can be made through the natural expansion of the electric public utilities, but if these utilities, which are the only instrumentalities through which maximum economy can be attained, will cooperate 100 per cent to the end that a coordinated expansion through interconnecting systems of transmission and distribution circuits shall be made, then the shortest route to a maximum national conservation of money, labor, and material will have been mapped out. To show that such a project is feasible and would be profitable was the task that confronted my organization on July 1, 1920.

APPENDIX B.

ELECTRIC UTILITIES IN INDEPENDENT OPERATION IN THE SUPERPOWER ZONE IN 1919.

By L. E. Imlay, T. B. Rutherford, and others of the engineering staff.

DEMAND AND OUTPUT.

Table 1 shows the distribution of load, the demand, and the requirements of energy for electric utilities in the superpower zone in 1919 and the frequencies in use.

Table 1.—*Distribution of load, by geographic divisions and load centers, for electric utilities in the superpower zone in 1919.*

Geographic division and load center.	Maximum demand (thousands of kilowatts).				Energy output (millions of kilowatt-hours).			
	25 cycles.	60 cycles.	Other frequencies.	Total.	25 cycles.	60 cycles.	Other frequencies.	Total.
Eastern New England:								
Boston	68.06	122.14	52.96	243.16	240.18	380.72	151.77	772.67
Lowell	4.56	62.18	1.82	68.56	13.85	176.05	7.11	197.01
Providence	25.80	128.95	6.02	160.77	65.87	370.27	14.66	450.80
Worcester	11.00	86.81	2.52	100.33	30.60	314.24	7.09	351.93
	109.42	400.08	63.32	572.82	350.50	1,241.28	180.63	1,772.41
Western New England:								
Hartford	6.60	50.47	3.98	61.05	26.02	133.66	7.87	167.55
New Haven	33.68	90.47	21.06	145.21	133.00	248.30	54.77	436.07
Northampton	4.60	94.04	9.23	107.87	14.14	293.64	10.59	318.37
	44.88	234.98	34.27	314.13	173.16	675.60	73.23	921.99
Mohawk:								
Utica	1.57	25.36	.14	27.07	5.86	78.02	.37	84.25
Schenectady	13.10	8.50	87.20	108.80	30.92	28.02	294.97	353.91
	14.67	33.86	87.34	135.87	36.78	106.04	295.34	438.16
Metropolitan:								
Newark	27.00	154.18	12.14	193.32	121.27	594.26	15.64	731.17
New York	809.00	148.79	13.89	971.68	2,648.99	477.34	9.17	3,135.50
	836.00	302.97	26.03	1,165.00	2,770.26	1,071.60	24.81	3,866.67
Hudson:								
Poughkeepsie	0	20.05	1.45	21.50	0	59.33	1.15	60.48
	0	20.05	1.45	21.50	0	59.33	1.15	60.48
Anthracite:								
Allentown	35.28	35.40	1.14	71.82	180.70	148.53	2.47	331.70
Pottsville	0	13.60	1.10	14.70	0	38.90	3.30	42.20
Wilkes-Barre	14.77	79.48	4.31	98.56	43.99	309.16	16.01	369.16
	50.05	128.48	6.55	185.08	224.69	496.59	21.78	743.06
Southern:								
Trenton	2.35	10.03	3.70	16.08	7.64	26.60	10.30	44.54
Harrisburg	.88	69.72	6.09	76.69	3.87	234.91	20.67	259.45
Philadelphia	107.70	241.88	19.25	368.83	365.31	848.32	66.11	1,279.74
Baltimore	111.57	2.54	17.88	131.99	669.52	7.37	3.53	680.42
Washington	66.50	0	.60	67.10	231.71	0	2.50	234.21
	289.00	324.17	47.52	660.69	1,278.05	1,117.20	103.11	2,498.36
Superpower zone	1,344.02	1,444.59	266.48	3,055.09	4,833.44	4,767.64	700.05	10,301.13

DISTRIBUTION OF POWER.

Figure 1 shows the electric-utility load at all the load centers in the superpower zone in 1919. A study of this load chart in combination with the analysis of load growth (p. 34) brings out the striking fact that the power required in 1930, the greater part of which will be applied to industrial uses, will be 2½ times that required to-day.

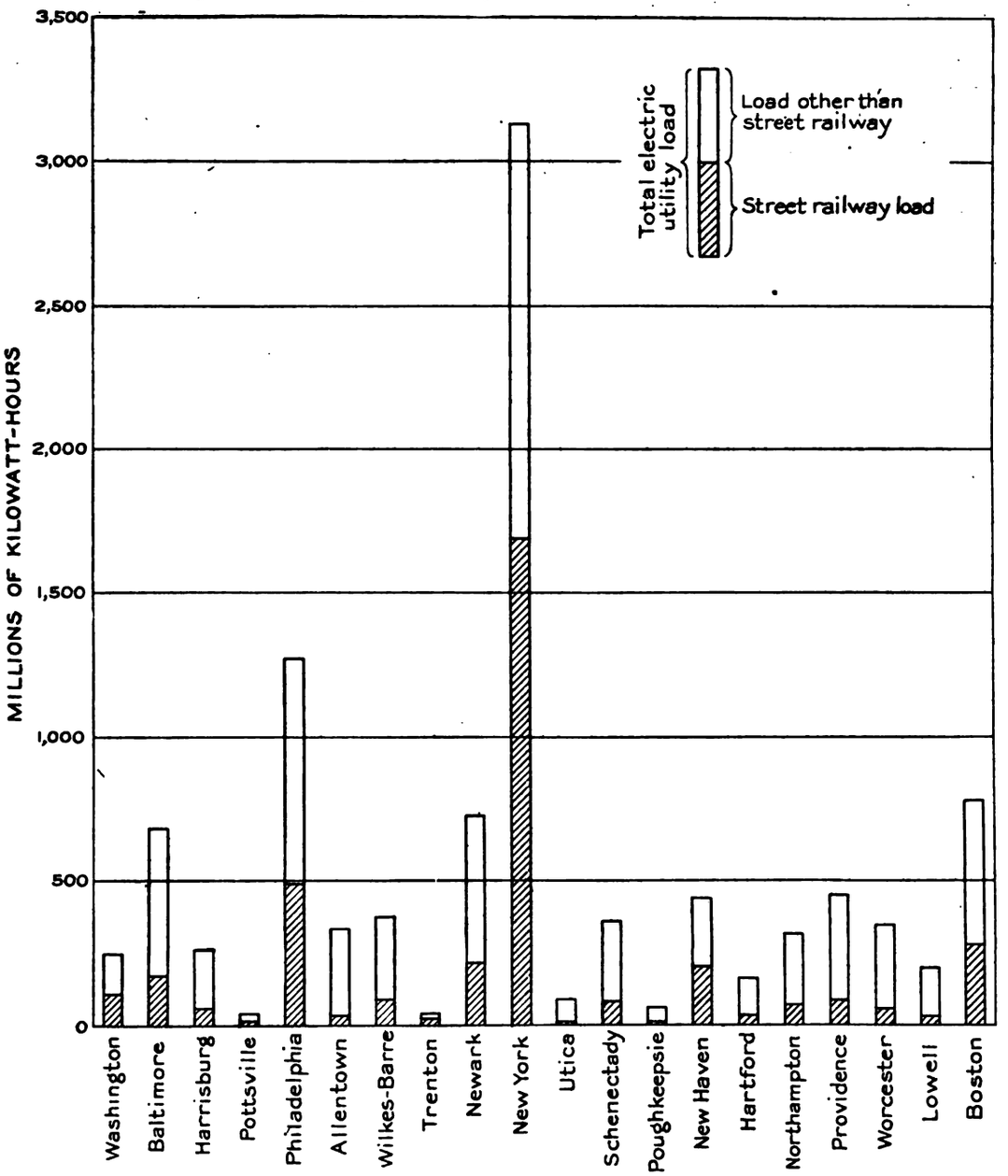


FIGURE 1.—Distribution of electric-utility load among load centers of superpower zone in 1919.

More than 50 per cent of the power generated at the present New York load center is used by the electric railways, whose slower rate of growth of load as compared with that in power for domestic and industrial uses will have the effect of decentralizing the total load on the superpower system by 1930. This effect is shown in Appendix E. The superpower system will become a means to this end.

PAST AND ESTIMATED FUTURE GROWTH OF LOAD.

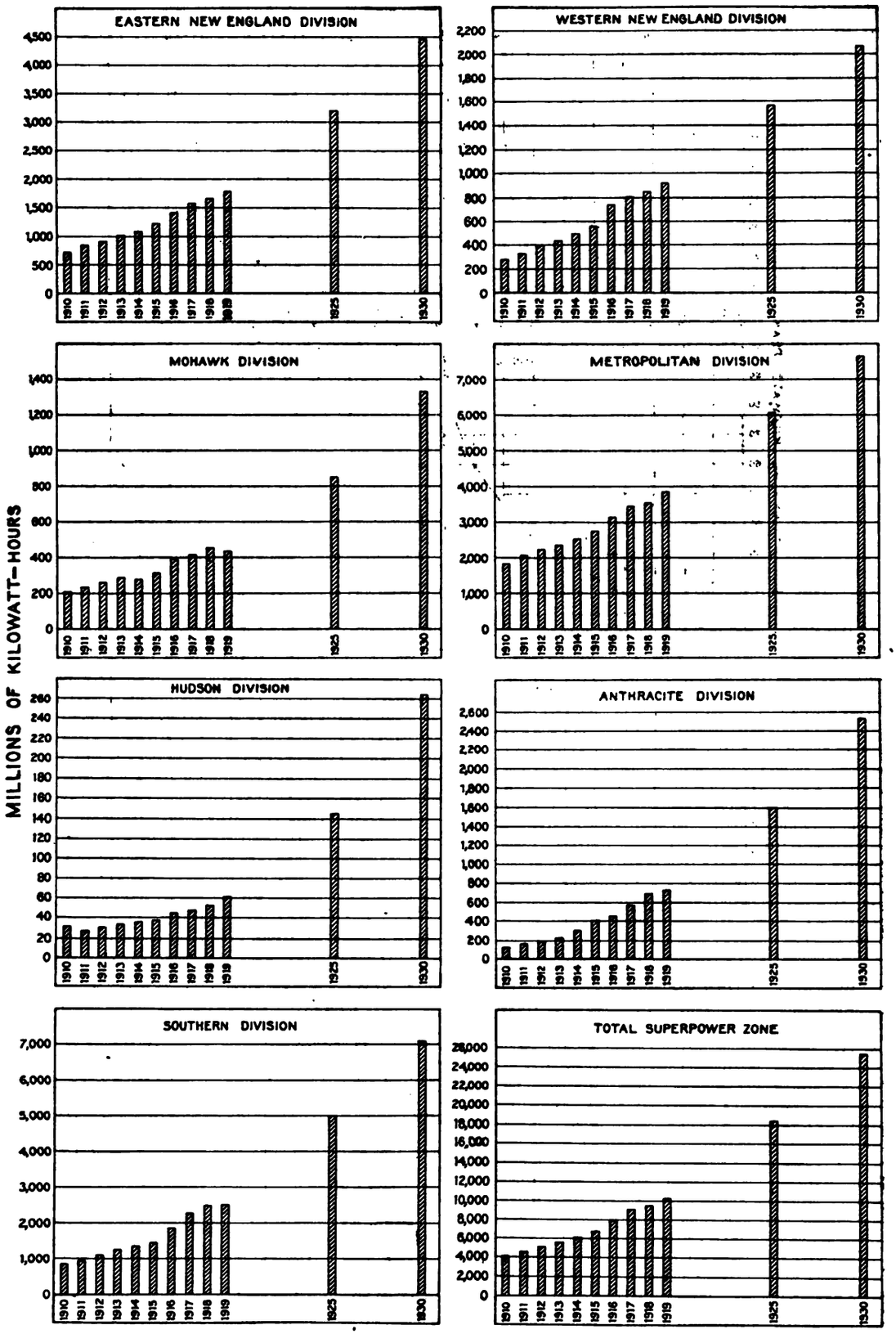
Plate IV shows the growth of the electric-utility industry by geographic divisions and for the entire superpower zone during the 10 years ending with 1919 and the estimated growth by 1925 and 1930. The record of the past growth includes the energy used for lighting, industrial power, electric street railways, and the electrified heavy-traction railroads. The estimate of the future growth does not include demands that may arise from the electrified heavy-traction systems.

The future rate of load growth is estimated at 8.6 per cent, compounded annually. This estimate is based upon the projection of past load growths taken in combination with opinions expressed by the operators of the electric-utility properties. The average annual growth during the last 10 years was 9 per cent.

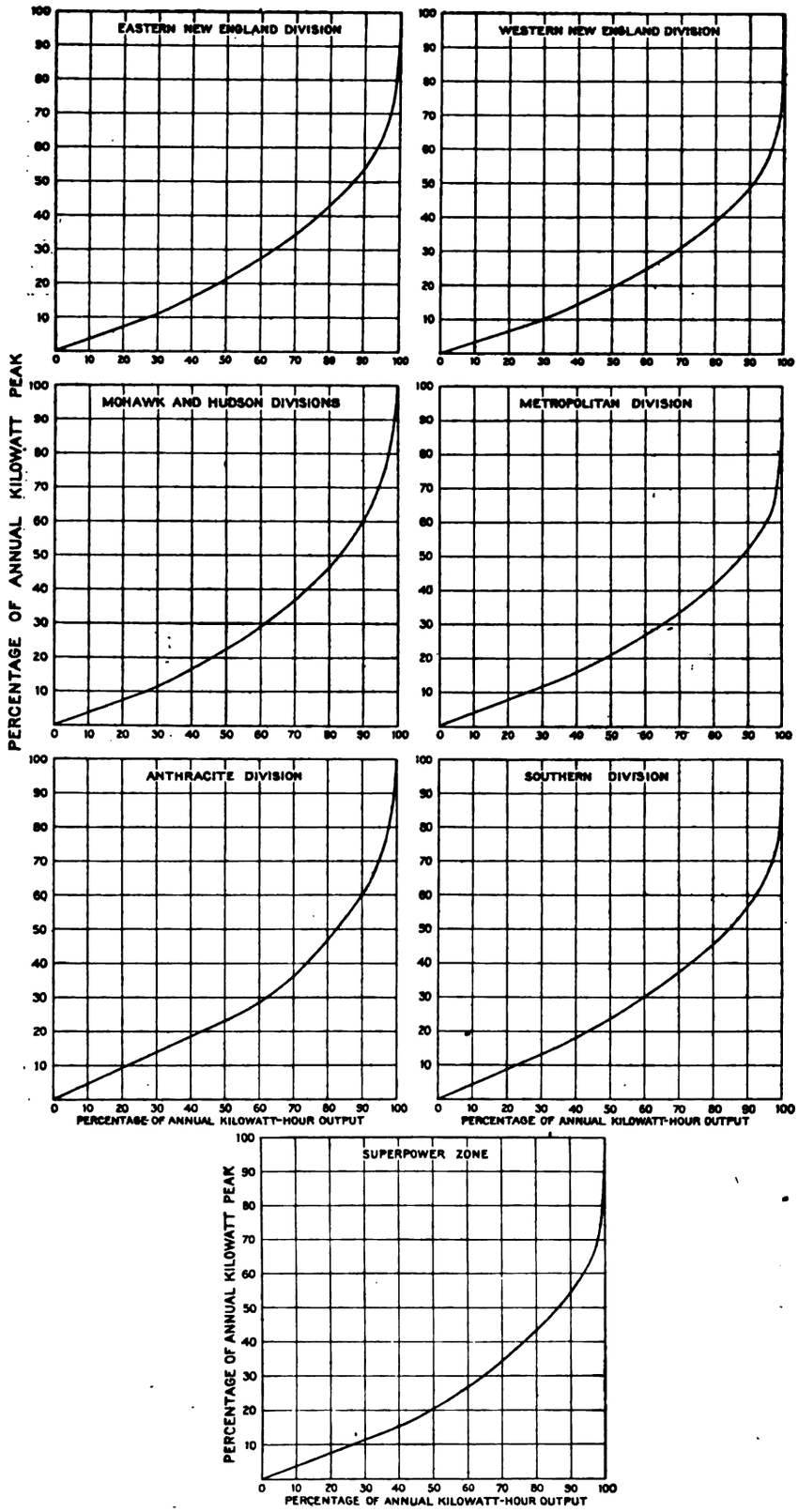
LOADS CARRIED.

Figures 2–8, which are plotted from data furnished by the electric public-utility companies in the superpower zone, show the typical week-day, Saturday, and Sunday loads and also the demand for the day of peak load in 1919.

Plate V shows the relation of energy generated in kilowatt-hours to the demand in kilowatts for the several geographic divisions of the superpower zone in 1919. They show that only about 14 per cent of the energy generated in the zone is produced by the last 50 per cent of the demand. This indicates that the peak load should be carried by the less efficient steam-electric plants and by overdeveloped hydroelectric plants, because when the dam and headworks of a hydroelectric plant are once installed the cost of the generating apparatus for the plant is only half that of the total cost of a steam-electric plant.



PAST AND ESTIMATED FUTURE GROWTH OF LOAD OF ELECTRIC PUBLIC UTILITIES IN SUPERPOWER ZONE, 1910-1930.



DISTRIBUTION OF LOAD FOR ELECTRIC PUBLIC UTILITIES IN SUPERPOWER ZONE IN 1919.

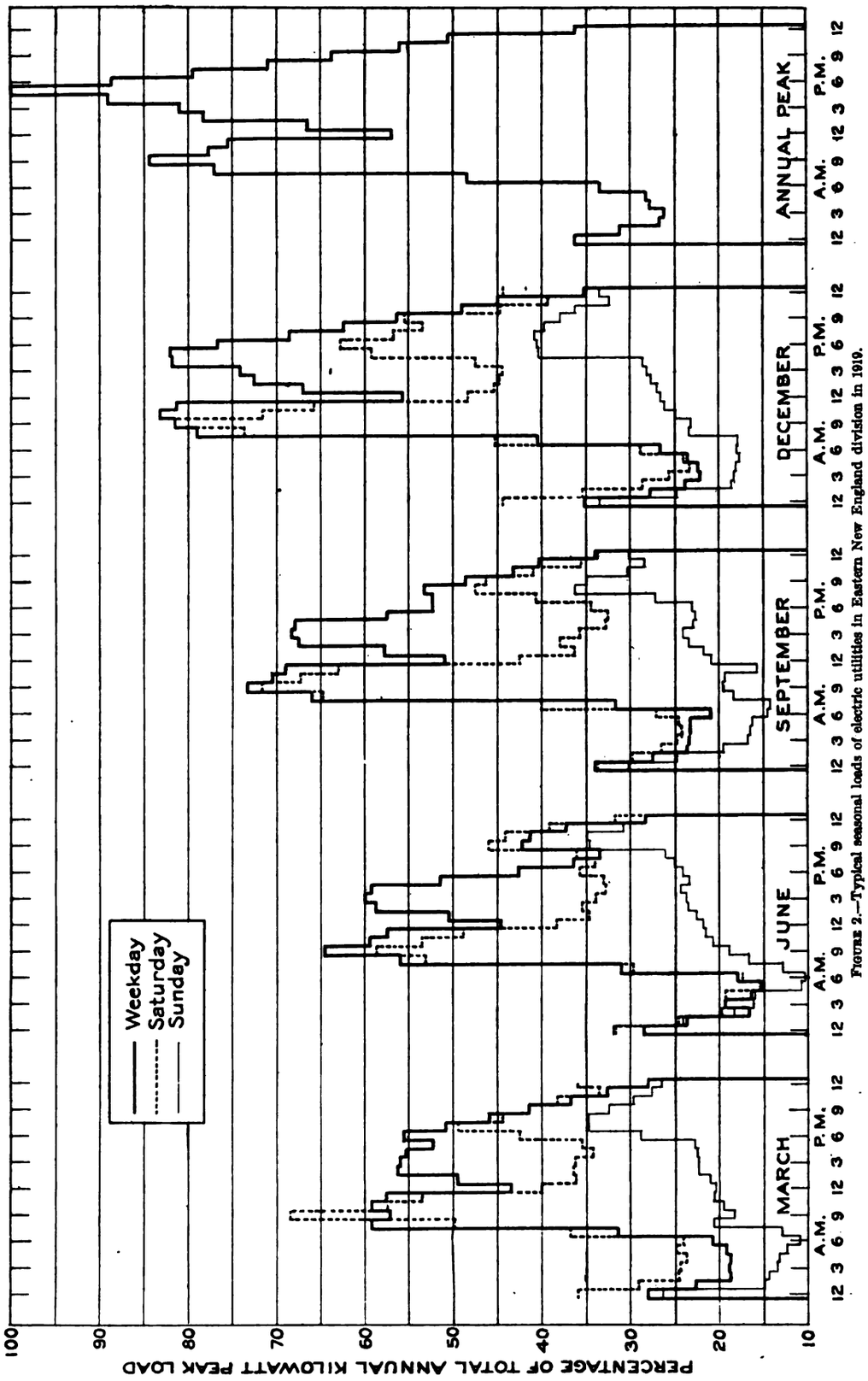


FIGURE 2.—Typical seasonal loads of electric utilities in Eastern New England division in 1919.

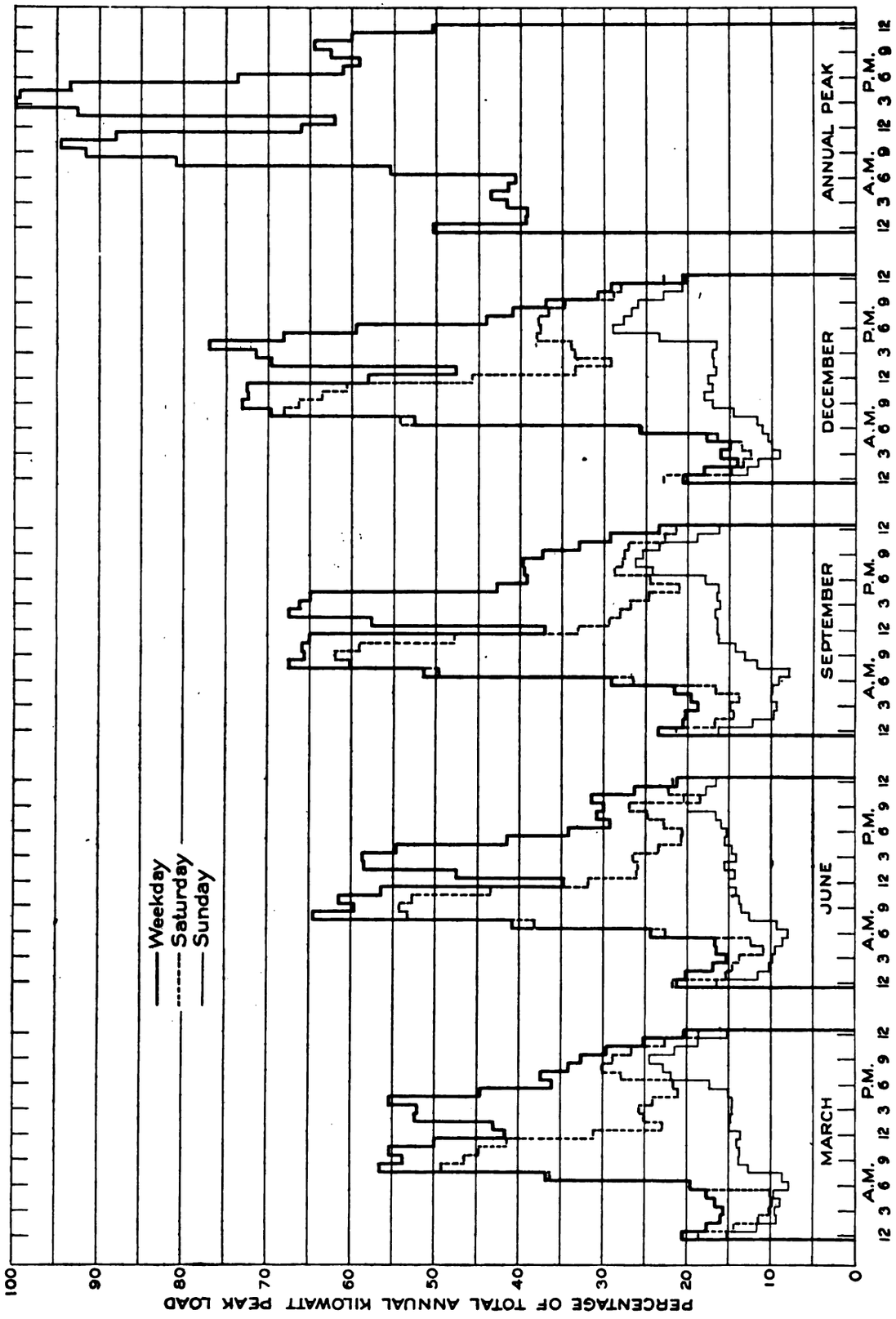


FIGURE 3.—Typical seasonal loads of electric utilities in Western New England division in 1919.

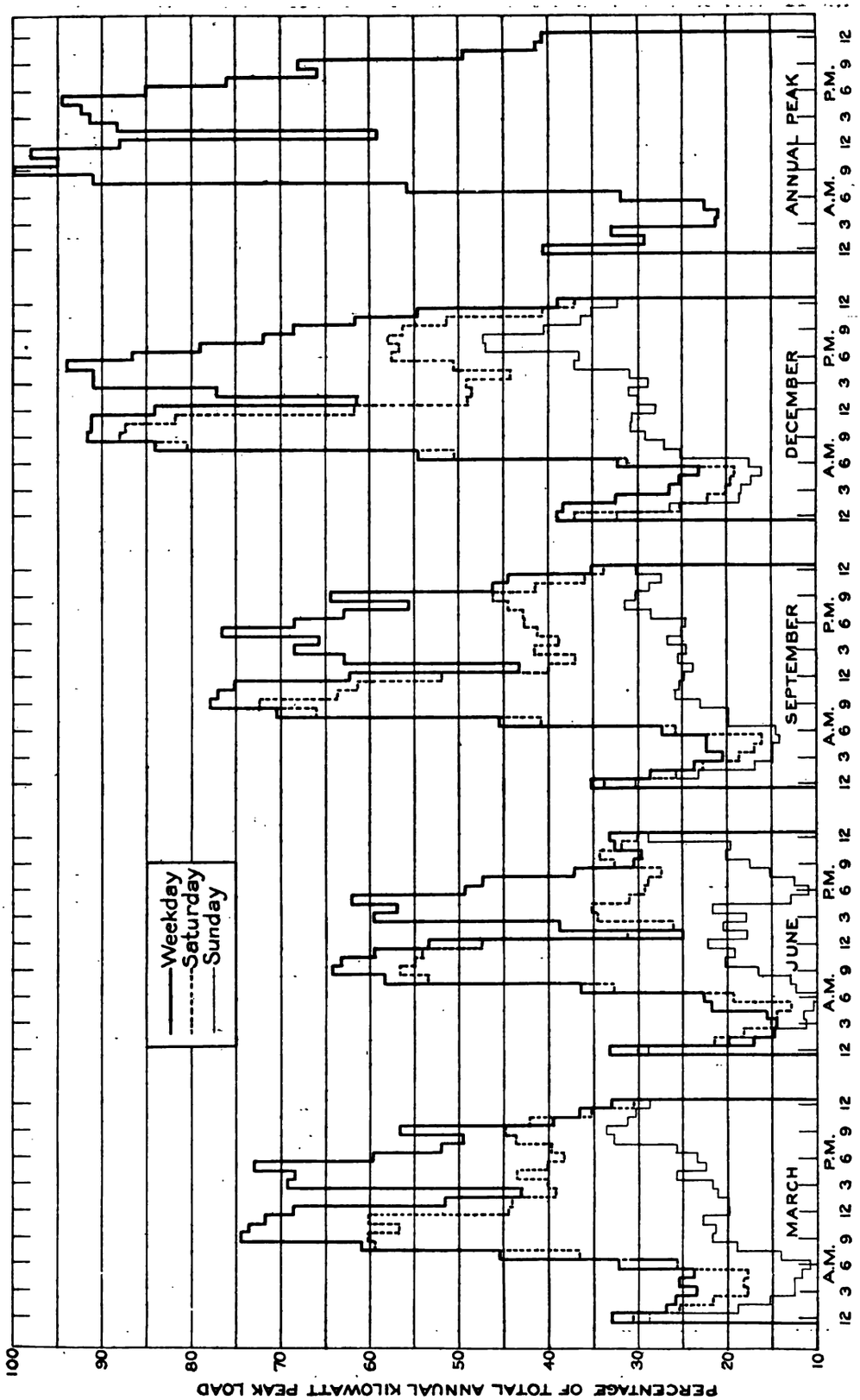


FIGURE 4.—Typical seasonal loads of electric utilities in Mohawk and Hudson divisions in 1919.

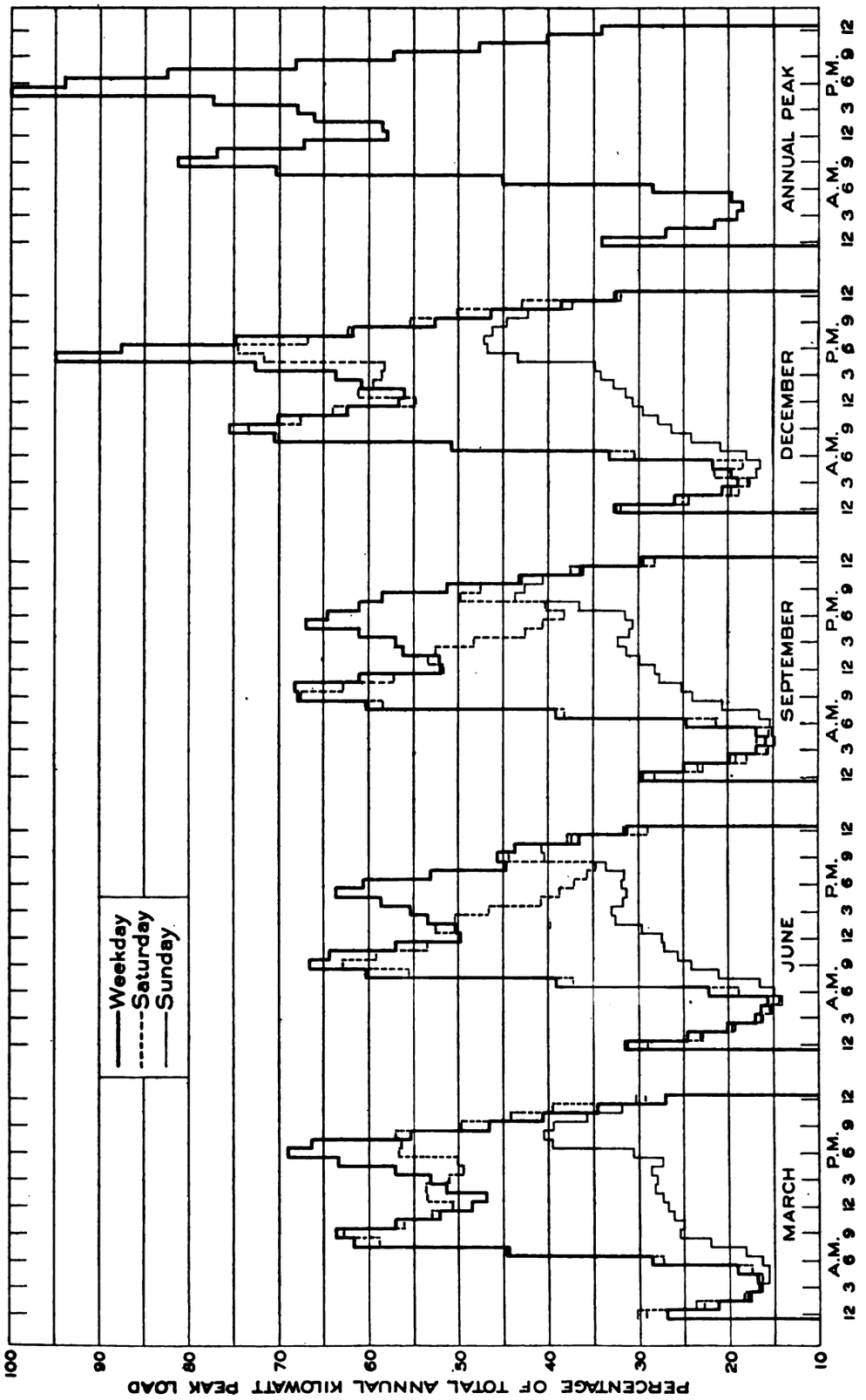


FIGURE 5.—Typical seasonal loads of electric utilities in Metropolitan division in 1919.

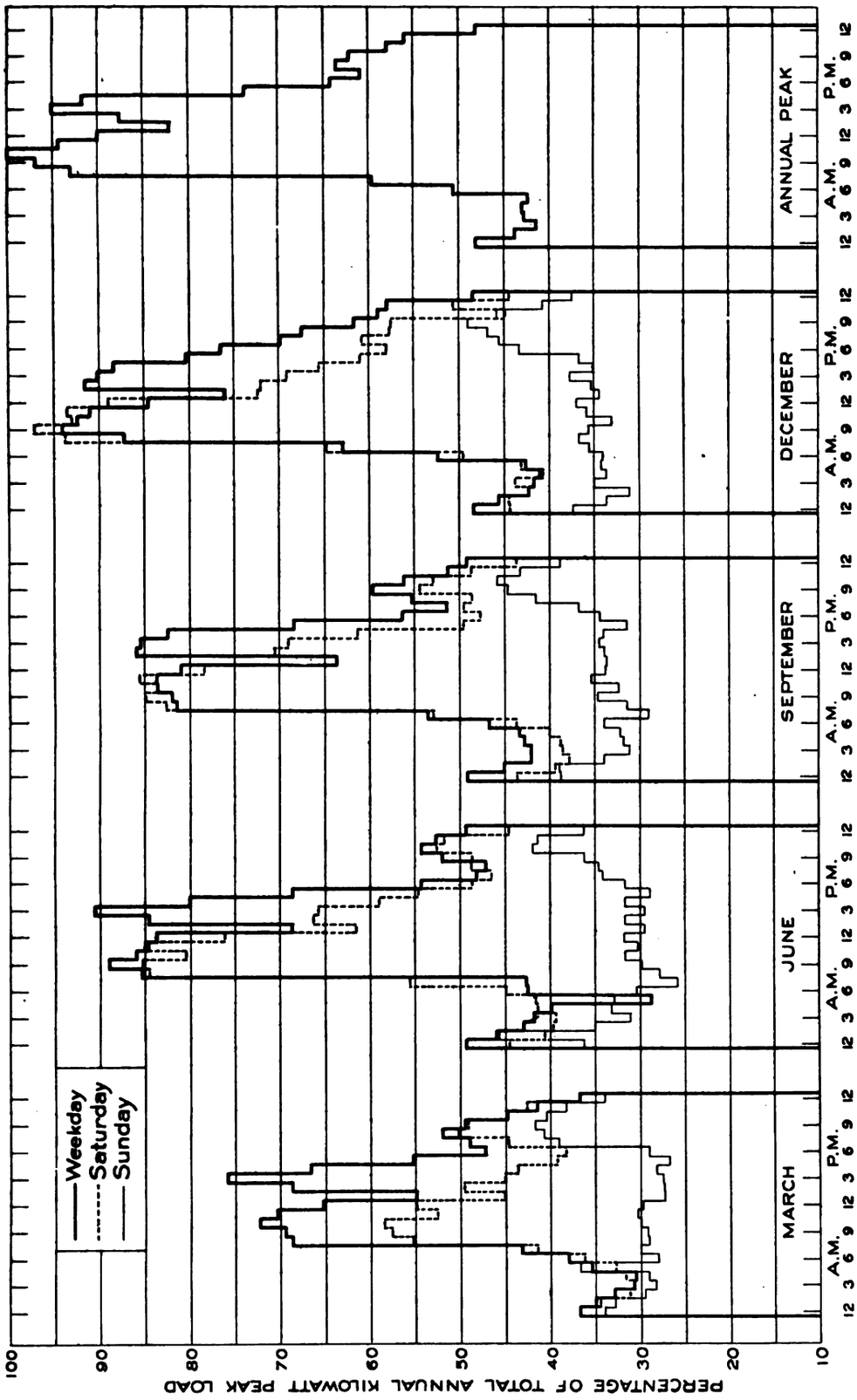


FIGURE 6.—Typical seasonal loads of electric utilities in Anthracite division in 1919.

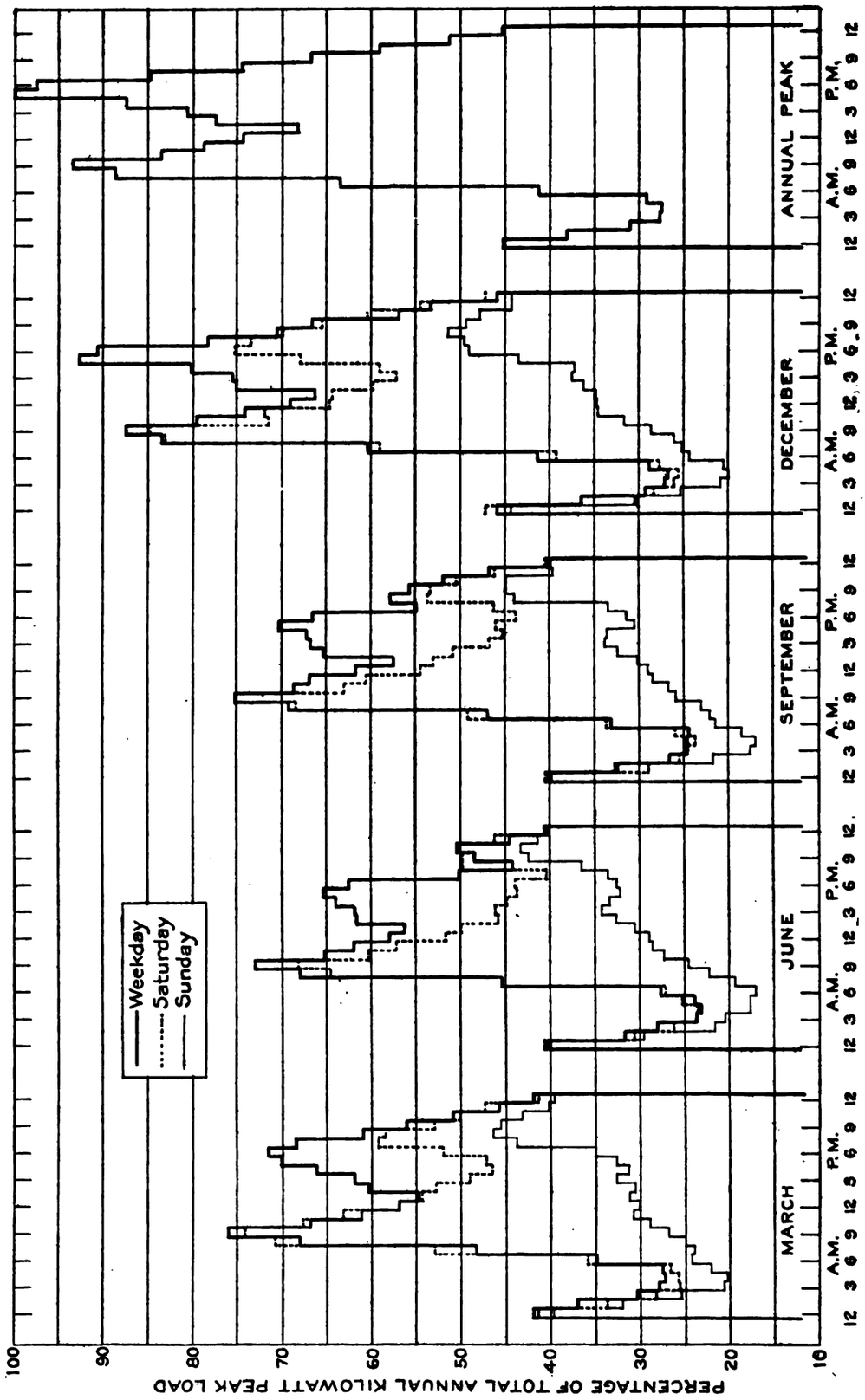


FIGURE 7.—Typical seasonal loads of electric utilities in Southern division in 1919.

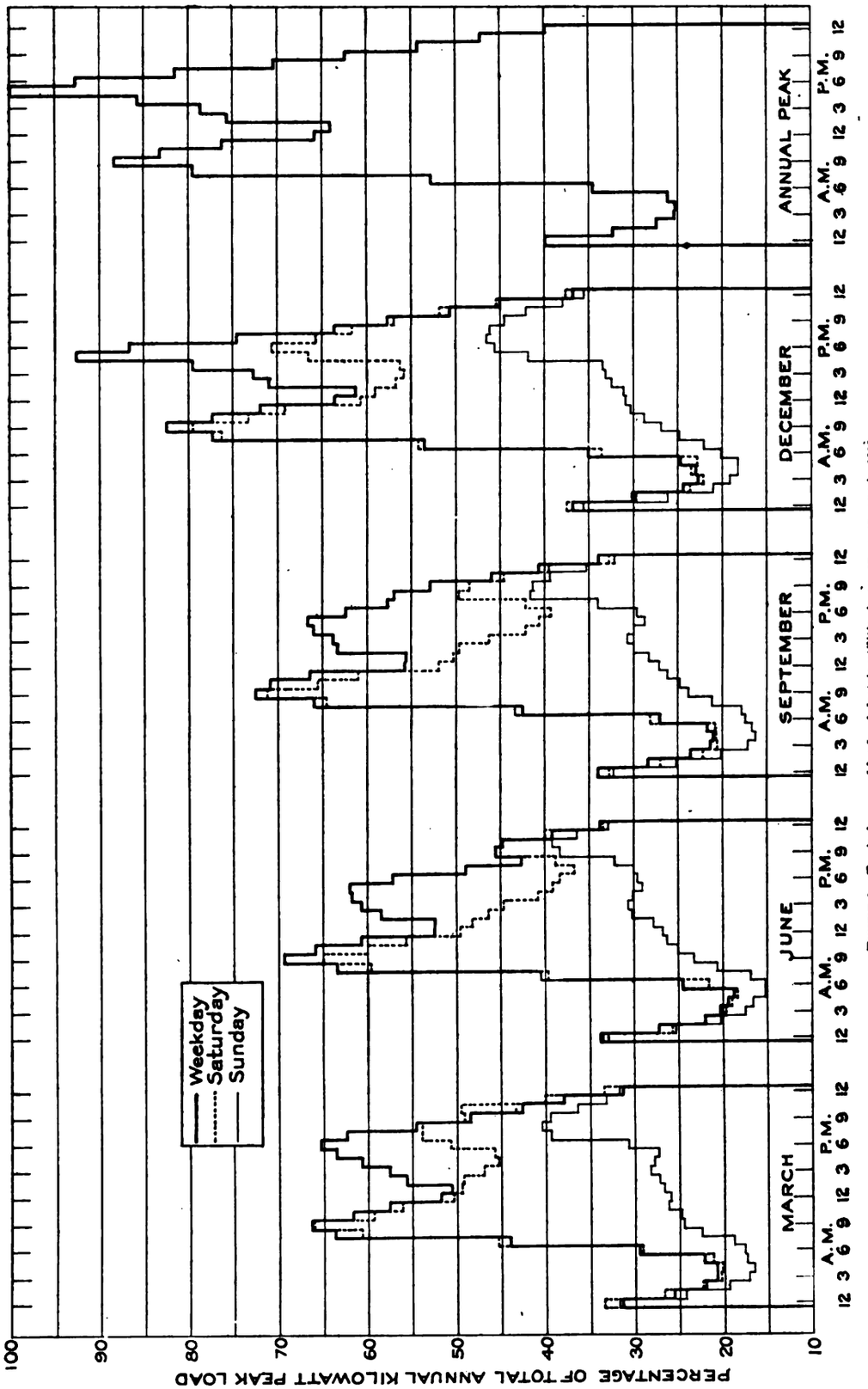


FIGURE 8.—Typical seasonal loads of electric utilities in superpower zone in 1919.

CAPACITY AND NUMBER OF POWER PLANTS.

Table 2 shows the capacity of power plants in the superpower zone, classified into steam-electric and hydroelectric and as to frequency.

TABLE 2.—*Capacity of steam-electric and hydroelectric power plants of electric utilities in the superpower zone in 1919.*

Geographic division and load center.	Steam-electric capacity (thousands of kilowatts).				Hydroelectric capacity (thousands of kilowatts).				Total capacity (thousands of kilowatts).
	25 cycles.	60 cycles.	Other frequencies.	Total.	25 cycles.	60 cycles.	Other frequencies.	Total.	
Eastern New England:									
Boston	131.80	184.78	76.63	393.21	0	5.70	0	5.70	398.91
Lowell	5.50	72.00	3.17	80.67	0	17.88	0.08	17.96	98.63
Providence	42.35	196.84	13.55	252.74	0	1.75	0	1.75	254.49
Worcester	10.00	76.83	2.25	89.08	8.60	61.58	0.41	70.59	159.67
	189.65	530.45	95.60	815.70	8.60	86.91	0.49	96.00	911.70
Western New England:									
Hartford	6.70	43.48	4.65	54.83	0	13.35	0	13.35	68.18
New Haven	51.95	131.17	22.99	206.11	.60	29.93	.57	31.10	237.21
Northampton	13.00	88.39	7.12	108.51	0	65.69	1.39	67.08	175.59
	71.65	263.04	34.76	369.45	.60	108.97	1.96	111.53	480.98
Mohawk:									
Utica	1.75	16.54	0	18.29	2.54	22.20	.12	24.86	43.15
Schenectady	7.00	1.88	31.10	39.98	7.29	10.02	73.98	91.29	131.27
	8.75	18.42	31.10	58.27	9.83	32.22	74.10	116.15	174.42
Metropolitan:									
Newark	38.35	204.71	16.90	259.96	0	8.13	.03	8.16	268.12
New York	1,110.60	242.73	16.53	1,369.86	0	.55	0	.55	1,370.41
	1,148.95	447.44	33.43	1,629.82	0	8.68	.03	8.71	1,638.53
Hudson:									
Poughkeepsie	0	25.82	1.01	26.83	0	8.69	0	8.69	35.52
	0	25.82	1.01	26.83	0	8.69	0	8.69	35.52
Anthracite:									
Pottsville	0	14.19	2.31	16.50	0	.14	0	.14	16.64
Allentown	37.20	42.25	1.55	81.00	0	2.51	0	2.51	83.51
Wilkes-Barre	19.45	91.25	9.61	120.31	0	2.43	0	2.43	122.74
	56.65	147.69	13.47	217.81	0	5.08	0	5.08	222.89
Southern:									
Trenton	2.10	15.14	5.83	23.07	.75	0	0	.75	23.82
Harrisburg	0	68.50	7.17	75.67	.88	15.82	0	16.70	92.37
Philadelphia	151.80	295.74	34.00	481.54	2.70	.65	.03	3.38	484.92
Baltimore	191.00	4.93	6.60	202.53	84.10	.41	0	84.51	287.04
Washington	98.00	0	1.57	99.57	0	0	0	0	99.57
	442.90	384.31	55.17	882.38	88.43	16.88	.03	105.34	987.72
Superpower zone	1,918.55	1,817.17	264.54	4,000.26	107.46	267.43	76.61	451.50	4,451.76

Figure 9 shows the number of power plants of different generator capacities among 280 of the larger electric-utility plants in the superpower zone in 1919. The average size of plant for all the utilities was 7,900 kilowatts, and there were 104 plants of this or greater capacity.

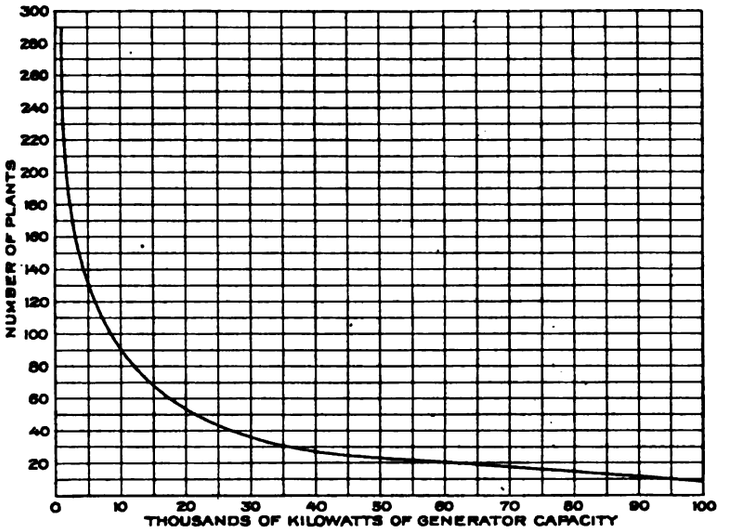


FIGURE 9.—Number of generating plants of different capacities owned by 280 of the electric-utility companies in the superpower zone in 1919.

Figure 10 shows the number of generating units of different sizes among 1,074 units of 500 kilowatts or more in the superpower zone in 1919. The average size of unit for all the utilities was 2,700 kilovolt-amperes, and the number of units of this size or greater capacity was 420. The capacity of the units to be installed in future superpower plants will be more than three times that of the plant of average size now in the zone.

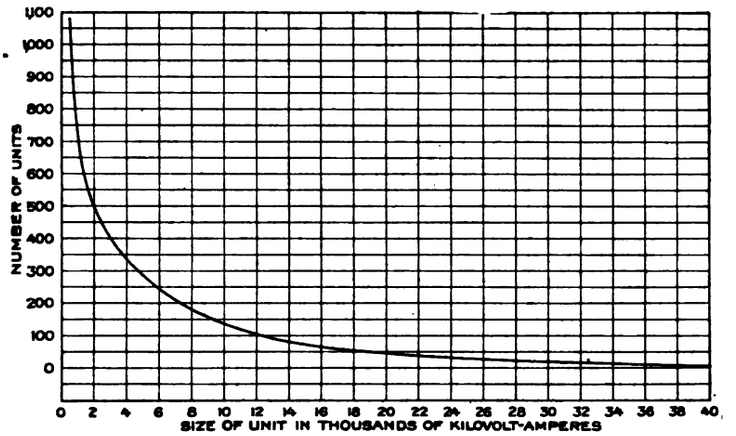


FIGURE 10.—Number of generating units of different sizes over 500 kilowatts owned by the electric-utility companies in the superpower zone in 1919.

PERFORMANCE.

Table 3 shows the performance of 400 steam-electric and 158 hydroelectric power plants in the superpower zone in 1919. The effective capacity of steam-electric plants, though not of hydroelectric plants, is usually less than their generator capacity, being generally limited by boiler capacity.

TABLE 3.—*Character and performance of electric-utility plants in the superpower zone in 1919.*

Geographic division and load center.	Existing generating plants.			Generator capacity (thousands of kilowatts).			Effective capacity (thousands of kilowatts).		
	Steam-electric.	Hydro-electric.	Total.	Steam-electric plants.	Hydro-electric plants.	Total.	Steam-electric plants.	Hydro-electric plants.	Total.
Eastern New England:									
Boston	34	1	35	393.21	5.70	398.91	321.95	5.70	327.65
Lowell	25	15	40	80.67	17.96	98.63	75.23	17.96	93.19
Providence	19	1	20	252.74	1.75	254.49	190.63	1.75	192.38
Worcester	8	10	18	89.08	70.59	159.67	64.38	70.59	134.97
	86	27	113	815.70	96.00	911.70	652.19	96.00	748.19
Western New England:									
Hartford	12	6	18	54.83	13.35	68.18	53.56	13.35	66.91
New Haven	24	10	34	206.11	31.10	237.21	174.63	31.10	205.73
Northampton	16	22	38	108.51	67.08	175.59	91.05	67.08	158.13
	52	38	90	369.45	111.53	480.98	319.24	111.53	430.77
Mohawk:									
Utica	16	18	34	18.29	24.86	43.15	17.79	24.86	42.65
Schenectady	14	27	41	39.98	91.29	131.27	38.10	91.29	129.39
	30	45	75	58.27	116.15	174.42	55.89	116.15	172.04
Metropolitan:									
Newark	25	8	33	259.96	8.16	268.12	223.71	8.16	231.87
New York	53	2	55	1,369.86	.55	1,370.41	1,119.05	.55	1,119.60
	78	10	88	1,629.82	8.71	1,638.53	1,342.76	8.71	1,351.47
Hudson:									
Poughkeepsie	13	13	26	26.83	8.69	35.52	23.11	8.69	31.80
	13	13	26	26.83	8.69	35.52	23.11	8.69	331.80
Anthracite:									
Pottsville	11	0	11	16.50	.14	16.64	13.20	.14	13.34
Allentown	6	6	12	81.00	2.51	83.51	75.50	2.51	78.01
Wilkes-Barre	23	4	27	120.31	2.43	122.74	107.40	2.43	109.83
	40	10	50	217.81	5.08	222.89	196.10	5.08	201.18
Southern:									
Trenton	16	1	17	23.07	.75	23.82	18.05	.75	18.80
Harrisburg	17	6	23	75.67	16.70	92.37	65.20	16.70	81.90
Philadelphia	51	4	55	481.54	3.38	484.92	422.86	3.38	426.24
Baltimore	14	4	18	202.53	84.51	287.04	185.30	84.51	269.81
Washington	3	0	3	99.57	0	99.57	99.57	.00	99.57
	101	15	116	882.38	105.34	987.72	790.98	105.34	896.32
Superpower zone	400	158	558	4,000.26	451.70	4,451.76	3,380.27	451.50	3,831.77

TABLE 3.—*Character and performance of electric-utility plants in the superpower zone in 1919*—Continued.

Geographic division and load center.	Generator reserve in steam-electric plants.		Effective reserve in steam-electric plants.		Generated output (millions of kilowatt-hours).			Annual effective capacity factor (per cent).		
	Total (thousands of kilowatts).	Per cent.	Total (thousands of kilowatts).	Per cent.	Steam-electric plants.	Hydro-electric plants.	Total.	Steam-electric plants.	Hydro-electric plants.	Total.
Eastern New England:										
Boston	136.41	53.1	65.15	25.4	759.16	13.52	772.68	26.9	27.1	26.9
Lowell	30.06	59.2	24.62	48.7	143.81	53.20	197.01	21.8	33.8	24.1
Providence	91.90	57.2	29.79	18.5	445.79	5.00	450.79	26.7	32.6	26.7
Worcester	30.35	51.7	5.65	9.6	131.11	220.82	351.93	23.3	35.7	29.8
	288.72	54.8	125.21	23.8	1,479.87	292.54	1,772.41	25.9	34.8	27.1
Western New England:										
Hartford	6.74	14.0	5.48	11.4	115.22	52.33	167.55	24.5	44.7	28.6
New Haven	70.80	52.3	39.32	29.0	379.58	56.49	436.07	24.8	20.7	24.2
Northampton	40.78	60.2	23.32	34.4	123.74	194.63	318.37	15.5	33.1	23.0
	118.32	47.2	68.12	27.2	618.54	303.45	921.99	22.1	31.1	24.5
Mohawk:										
Utica	2.18	13.5	1.68	10.4	17.42	66.83	84.25	11.2	30.6	22.6
Schenectady	18.83	89.1	16.95	80.2	30.33	323.58	353.91	9.1	40.5	31.1
	21.01	56.5	18.63	50.0	47.75	390.41	438.16	9.7	38.3	29.1
Metropolitan:										
Newark	152.02	73.3	15.77	7.5	707.82	23.35	731.17	36.2	32.6	36.0
New York	353.06	34.8	102.25	10.0	3,134.15	1.35	3,135.50	32.1	28.0	32.1
	405.08	33.1	118.02	9.6	3,841.97	24.70	3,866.67	32.6	32.3	32.6
Hudson:										
Poughkeepsie	10.28	62.0	6.56	39.7	37.68	22.80	60.48	18.6	30.0	21.6
	10.28	62.0	6.56	39.7	37.68	22.80	60.48	18.6	30.0	21.6
Anthracite:										
Pottsville	1.80	12.2	0.	0	42.17	.03	42.20	36.4	24.4	36.1
Allentown	1.63	2.0	0.	0.	317.98	13.72	331.70	48.0	62.4	48.5
Wilkes-Barre	18.40	18.0	5.49	5.4	365.69	3.47	369.16	38.8	16.3	38.4
	21.83	11.1	5.49	2.8	725.84	17.22	743.06	42.2	38.6	42.2
Southern:										
Trenton	7.74	50.5	2.62	17.1	41.87	2.67	44.54	26.4	40.6	27.1
Harrisburg	16.33	27.6	5.86	9.9	175.65	83.80	259.45	30.7	57.3	36.1
Philadelphia	81.48	20.4	22.8	5.7	1,259.10	20.64	1,279.74	34.0	69.7	34.2
Baltimore	106.50	111.0	89.27	93.0	175.46	504.96	680.42	10.8	68.2	28.8
Washington	33.19	50.0	33.19	50.0	234.21	.00	234.21	26.9	.0	26.9
	245.24	38.5	153.84	24.2	1,886.29	612.07	2,498.36	27.2	66.2	31.7
Superpower zone	1,110.49	38.4	490.50	17.0	8,637.94	1,663.19	10,301.13	29.1	42.2	30.7

A study of 196 steam-electric plants that use bituminous coal was made to ascertain their performance. These plants were selected from the 400 plants in the superpower zone because full and consistent data were available from each plant. Table 4 is a summary of the results of this study. The fuel consumption varies from 6.23 pounds per kilowatt-hour for the small plants to 2.14 pounds per kilowatt-hour for plants having a capacity of more than 100,000 kilowatts. Perhaps even more striking is the variation in the cost of maintenance, labor, and supplies, for this cost amounts to $23.10 per kilowatt-year of effective capacity for small plants but only to $5.46 for plants of more than 100,000 kilowatts.

The complete result of this study is given in figures 11 and 12, showing the performance and the operating cost, except the cost of fuel, which varies with size of plant, size of unit, and annual capacity factor.

TABLE 4.—*Performance and operating cost of 196 selected electric plants using bituminous coal in the superpower zone in 1919, by size of plant.*

	Under 1,000 kilowatts.	1,000 to 2,500 kilowatts.	2,500 to 5,000 kilowatts.	5,000 to 10,000 kilowatts.	10,000 to 25,000 kilowatts.	25,000 to 50,000 kilowatts.	50,000 to 100,000 kilowatts.	Over 100,000 kilowatts.	All plants.
Number of plants	33	36	32	29	31	14	13	8	196
Total generator capacity, kilowatts	23,485	62,061	121,575	230,500	507,675	476,100	905,400	1,318,600	3,645,396
Total effective capacity, kilowatts	21,530	54,308	106,200	202,875	449,597	393,600	721,000	1,048,450	3,000,560
Total generator reserve over peak, per cent	30.8	32.0	36.1	42.0	34.2	53.8	37.7	60.5	46.5
Total effective reserve over peak, per cent	19.8	13.2	19.0	25.0	18.8	27.1	9.7	27.5	20.6
Average size of plant effective capacity, kilowatts	650	1,510	3,320	7,000	14,500	28,000	55,500	131,000	15,300
Average size of unit, do	273	540	905	1,580	3,000	6,420	12,600	15,800	4,140
Load factor, per cent	21.3	24.5	27.3	24.7	28.5	32.4	38.8	37.3	34.2
Effective capacity factor, per cent	17.7	21.4	23.0	19.7	24.2	25.4	35.5	29.4	28.4
Fuel per kilowatt-year of effective capacity, short tons	4.85	3.96	3.64	3.30	3.21	2.80	3.42	2.76	3.10
Coal per kilowatt-hour, pounds	6.23	4.22	3.60	3.80	3.05	2.50	2.20	2.14	2.48
Cost of maintenance, labor, and supplies per kilowatt-year of effective capacity	$23.10	$18.10	$14.56	$12.21	$10.15	$6.82	$7.80	$5.46	$9.23

FUEL REQUIREMENTS.

Table 5 (p. 48) shows the quantities and cost of the coal used by electric utilities in the superpower zone in 1919 and the results in heat units. The total cost of this coal, delivered, was $63,227,812. The cost per short ton ranged from $2.79 at the Wilkes-Barre load center to $8.75 at the Lowell load center. The average cost for the zone was $5.35. The quantity of coal consumed ranged from 2.27 pounds per kilowatt-hour at the Providence load center to 6.23 pounds at the Utica load center. The Utica load center is, however, supplied largely by hydroelectric power; its steam-electric plants are small and are used principally as a reserve. The average quantity of coal consumed per kilowatt-hour in the superpower zone was 2.73 pounds, and the average heat utilization per kilowatt-hour was 35,800 British thermal units.

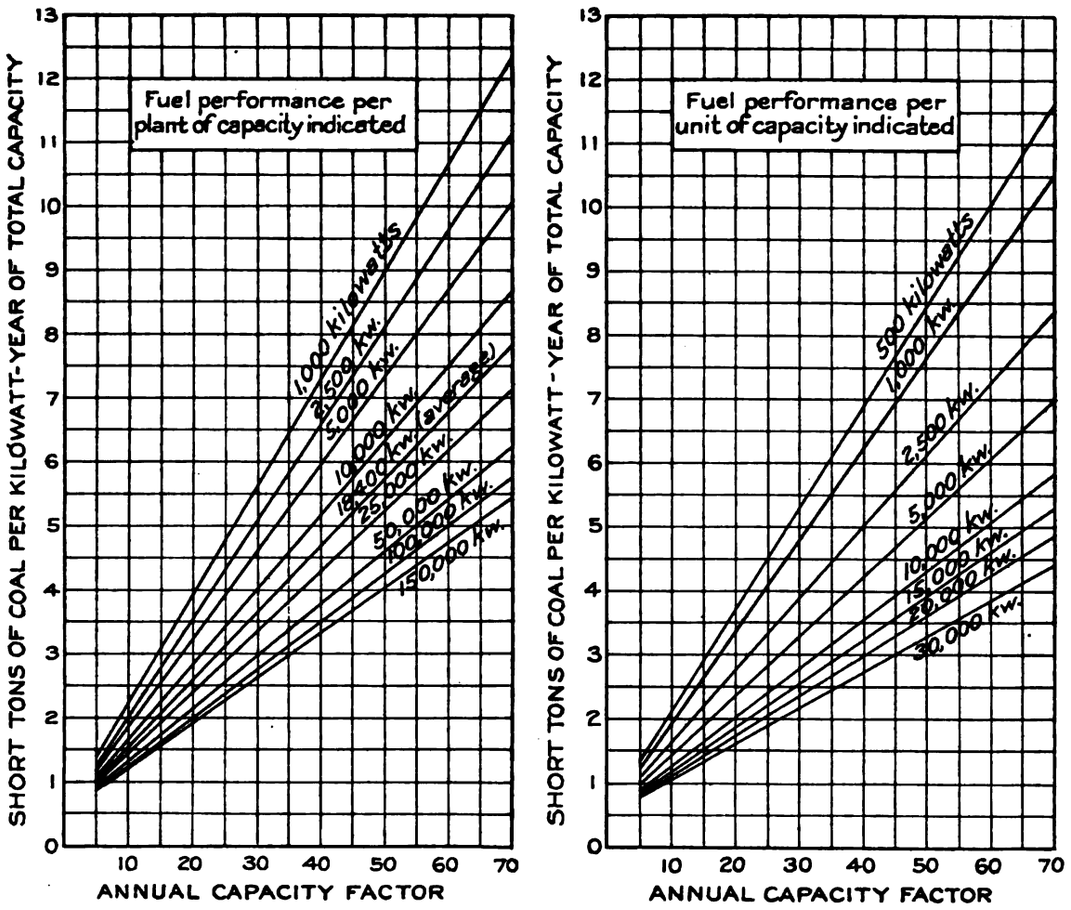


FIGURE 11.—Fuel performance in 1919 per plant and per unit of 196 electric-utility plants in the superpower zone that used bituminous coal.

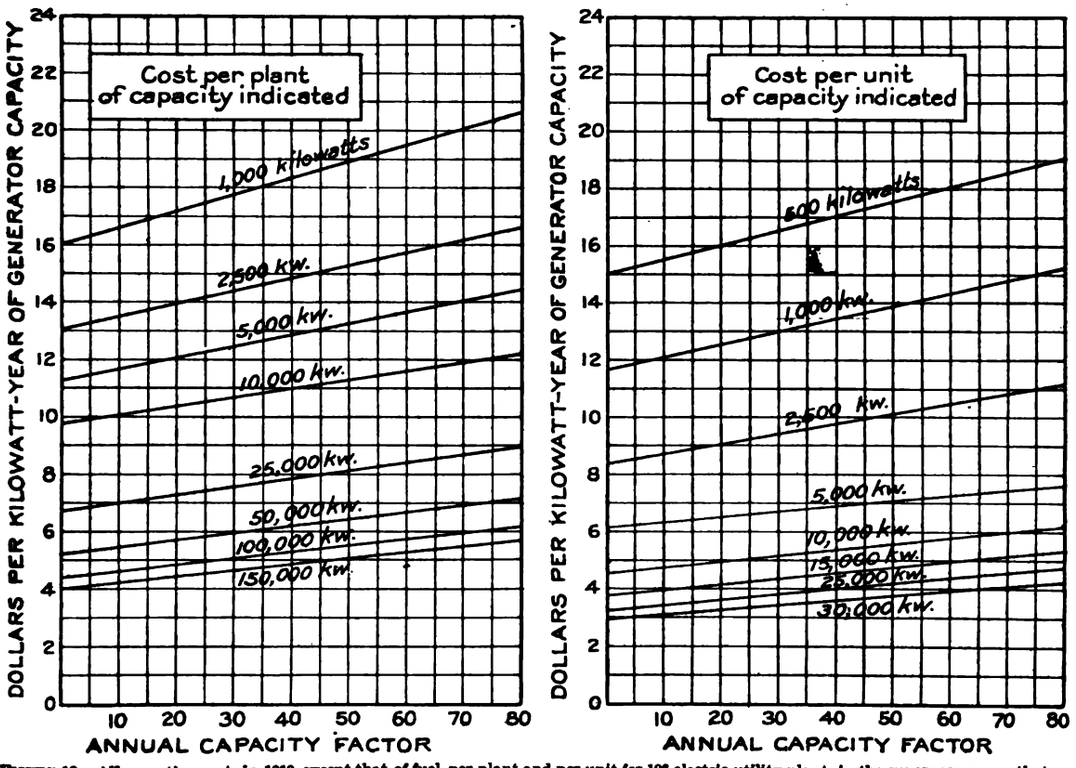


FIGURE 12.—All operating costs in 1919, except that of fuel, per plant and per unit for 196 electric-utility plants in the superpower zone that used bituminous coal.

TABLE 5.—*Fuel requirements and performance of electric utilities in the superpower zone in 1919.*

Geographic division and load center.	Coal used.					Heat value (thousands of British thermal units per kilowatt-hour).
	Thousands of short tons.	Short tons per kilowatt-year of effective capacity.	Pounds per kilowatt-hour.	Cost.		
				Per short ton.	Per year.	
Eastern New England:						
Boston	911.20	2.83	2.40	$6.50	$5,927,507.29	33.7
Lowell	179.11	2.38	2.49	8.75	1,568,282.26	33.3
Providence	506.06	2.66	2.27	7.70	3,891,543.19	31.5
Worcester	182.09	2.83	2.78	6.77	1,233,291.44	37.2
	1,778.46	2.73	2.40	7.10	12,620,624.18	33.4
Western New England:						
Hartford	158.33	2.96	2.75	6.63	1,049,624.24	37.6
New Haven	562.18	3.22	2.96	6.47	3,633,012.15	39.7
Northampton	184.77	2.03	2.99	6.73	1,241,529.15	40.7
	905.28	2.84	2.93	6.54	5,924,165.54	39.5
Mohawk:						
Utica	54.23	3.05	6.23	5.43	294,400.33	80.0
Schenectady	85.13	2.23	5.62	4.98	423,693.27	70.0
	139.36	2.50	5.85	5.15	718,093.60	73.7
Metropolitan:						
Newark	939.45	4.20	2.68	5.67	5,322,720.14	35.4
New York	3,800.01	3.40	2.42	5.61	21,322,522.19	32.2
	4,739.46	3.53	2.46	5.64	26,645,242.33	32.8
Hudson:						
Poughkeepsie	65.37	2.83	3.47	5.72	373,078.08	46.3
	65.37	2.83	3.47	5.72	373,078.08	46.3
Anthracite:						
Pottsville	99.73	7.55	4.73	3.32	331,463.33	55.4
Allentown	580.69	7.70	3.66	3.42	1,983,579.13	41.2
Wilkes-Barre	908.64	8.45	4.96	2.79	2,537,057.10	55.5
	1,589.06	8.10	4.38	3.05	4,852,099.56	49.2
Southern:						
Trenton	100.20	5.55	4.78	5.23	523,175.39	63.6
Harrisburg	331.79	5.08	3.78	3.28	1,088,894.93	41.7
Philadelphia	1,648.50	3.90	2.62	4.77	7,855,907.51	35.0
Baltimore	240.54	1.30	2.74	5.10	1,227,011.85	37.0
Washington	268.05	2.69	2.39	5.21	1,399,519.57	32.0
	2,589.08	3.28	2.74	4.67	12,094,509.25	36.1
Superpower zone	11,806.07	3.49	2.73	5.35	63,227,812.54	35.8

PRODUCTION COST.

Table 6 shows the production cost of the electric utilities in the superpower zone in 1919. The operating expense of the steam-electric plants was $91,195,000, of which 69 per cent was for coal and 31 per cent for maintenance, labor, and supplies. The total annual production cost of the steam plants was $183,441,333, of which the fixed charges were 44.5 per cent, the operating expense 49.7 per cent, and the general expense 5.8 per cent. The total annual production cost of the hydroelectric plants was $15,661,382, of which the fixed charges were 81 per cent, the operating expense 11.1 per cent, and the general expense 7.9 per cent. The average production cost by steam was $0.0212 per kilowatt-hour, and the average production cost by water was $0.0094 per kilowatt-hour.

TABLE 6.—*Annual production cost of electric utilities in the superpower zone, 1919.*

Geographic division.	Total annual operating expense.				Fixed charges.	
	Steam-electric plants.			Hydroelectric plants.	Steam-electric plants.	Hydroelectric plants.
	Fuel.	Maintenance, labor, and supplies.	Total.			
Eastern New England	$12,620,624	$5,479,617	$18,100,241	$388,192	$18,532,300	$2,394,350
Western New England	5,924,166	2,827,322	8,751,488	438,337	8,263,600	2,476,820
Mohawk	718,094	613,092	1,331,186	376,327	1,592,600	3,541,200
Metropolitan	26,645,242	10,913,651	37,558,893	67,330	29,143,100	369,800
Hudson	373,078	208,774	581,852	69,904	706,000	245,630
Anthracite	4,852,100	2,503,538	7,355,638	63,687	5,167,200	183,510
Southern	12,094,509	5,421,743	17,516,252	340,449	18,269,570	3,474,700
Superpower zone	63,227,313	27,967,737	91,195,550	1,744,226	81,674,370	12,686,010

Geographic division.	General expenses.		Total annual production cost.		Cost per kilowatt-hour.		Cost per kilowatt-year of effective capacity.	
	Steam-electric plants.	Hydroelectric plants.	Steam-electric plants.	Hydroelectric plants.	Steam-electric plants.	Hydro-electric plants.	Steam-electric plants.	Hydro-electric plants.
Eastern New England	$2,456,444	$222,256	$39,088,985	$3,004,798	$0.0264	$0.0102	$60.00	$31.30
Western New England	1,347,010	377,910	18,362,098	3,293,067	.0297	.0109	57.50	29.50
Mohawk	274,370	339,780	3,198,156	4,257,307	.0670	.0109	57.25	36.70
Metropolitan	3,096,990	40,800	69,798,983	477,930	.0182	.0194	52.00	54.90
Hudson	124,280	19,740	1,412,132	335,274	.0375	.0147	61.20	38.60
Anthracite	953,190	30,560	13,476,028	277,757	.0186	.0161	68.80	54.70
Southern	2,319,150	200,106	38,104,972	4,015,249	.0202	.0066	48.20	38.10
Superpower zone	10,571,434	1,231,146	183,441,354	15,661,382	.02124	.0094	54.30	34.70

REPRODUCTION COST.

Table 7 shows the cost of reproducing the electric-utility plants in the superpower zone as equipped in 1919. The total cost is $598,277,000, of which approximately 85.5 per cent is that of reproducing the steam-electric plants. The method used in arriving at these costs is stated in Appendixes F and G.

TABLE 7.—*Reproduction cost for electric public-utility power plants as of 1919.*

Geographic division.	Steam-electric plants.	Hydroelectric plants.	Total plants in superpower zone.	Percentage.	
				Steam-electric plants.	Hydro-electric plants.
Eastern New England	$115,949,000	$16,501,000	$132,450,000	87.5	12.5
Western New England	52,165,000	16,713,000	68,878,000	75.8	24.2
Mohawk	9,957,000	24,442,000	34,399,000	28.9	71.1
Metropolitan	181,899,000	2,550,000	184,449,000	98.6	1.4
Hudson	4,407,000	1,693,000	6,100,000	72.2	27.8
Anthracite	32,296,000	1,265,000	33,561,000	96.2	3.8
Southern	114,477,000	23,963,000	138,440,000	82.7	17.3
Superpower zone	511,150,000	87,127,000	598,277,000	85.5	14.5

APPENDIX C.

PROPOSED ELECTRIFICATION OF HEAVY-TRACTION RAILROADS IN THE SUPERPOWER ZONE.

By CARY T. HUTCHINSON, N. C. MCPHERSON, and others of engineering staff.

ADVANTAGES OF UNIFIED OPERATION.

Many of the railroad lines in the superpower zone have been built piecemeal to serve the interests of different communities as need arose, and consequently there has been considerable duplication of trackage and an unbalanced development. Consolidation subsequently improved the conditions, and the trackage now under steam operation in the zone is in general fully loaded.

Better results would be obtained, even under steam operation, by treating these systems as a unit. A substantial increase in traffic could be handled by better routing; by setting aside certain tracks for exclusive service where lines are parallel, as between Washington and Philadelphia or New York and Scranton; by eliminating competitive branch lines; and by abandoning branch lines that are unprofitable though not competitive. These improvements and many others have been discussed within the last few years, but no action has been taken.

Even after all possible improvements of this kind had been made, however, the railroad system would still be an inferior machine, with compromises in all its parts. The character and the cost of the service would not be essentially altered.

Unified operation by electricity, on the other hand, would give much better conditions than any that could possibly be attained under unified operation by steam. There would be a new motive power, in which all units or parts designed for similar service would be identical and interchangeable. There would be pooling of all power, with great reduction of reserves. Repair shops would be consolidated, and maintenance would become a standardized manufacturing job. Track capacity would be greatly increased, and certain tracks would be allocated to freight or passenger service exclusively. All freight trains would be run on schedule; the average speed would be more nearly the same and would be increased at least to the 12.5 miles an hour needed to avoid the present punitive overtime payments. Engine-house facilities would be much simplified by consolidation.

A specific illustration will show how wide the field is for possible savings under unified control. In 1919 one of the large railroads in the superpower zone spent about $20,000,000 for locomotive maintenance, and another spent about $40,000,000, the costs per locomotive-mile amounting, respectively, to 21 cents and 38 cents. Prorated to a weight of 100 tons on drivers, these costs become 24 cents and 46 cents, a difference of 90 per cent. The difference in average service is not sufficient to account for this difference in cost, which could not persist under unified control.

These improvements in operation can be made more readily under electric service than under steam, for a change in the power system would bring fresh minds into the service and would consequently liberate the mental operations of the average railroad man from their conventional routine. Under electric operation, for instance, the entire traffic between Philadelphia and Washington could readily be carried over the rails of the Pennsylvania system, those of the Baltimore & Ohio being left for future growth. Similarly, electric operation in the vicinity of Boston and New York would leave a margin of track capacity so great that no money need be spent for many years for further extensions of track. This release of trackage is one of the very notable advantages that would follow unified electric operation of the railroads in this territory. The great expense of any large increase in trackage should of itself force electrification; the total cost 20 years hence will be less if electrification is begun now than the cost of the added track

and terminal facilities necessary under steam operation to provide for the inevitable 100 per cent increase in traffic within that time.

The reserves of men and of machinery required for joint operation will be much less than the aggregate of the separate reserves required for individual operation. The great waste involved in the maintenance of separate reserves of motive power is exhibited by the operating statistics of the roads, quoted elsewhere, which show that the average freight locomotive in this territory is in productive service only 3,250 hours out of the 8,760 hours in a year, and the average passenger locomotive only 2,630 hours. With joint electric operation and consequent unification of types of motive power there would be a striking improvement. The steam locomotive runs 8 hours a day; the electric locomotive 20 hours.

The fundamental reason for coordinated control of railroad operations is precisely the same as that for regional control of the generation of electric energy. The greatest economy can be attained only by intelligent unified direction of the movements of all parts of the system for the best interests of the whole.

SPECIFIC ADVANTAGES OF ELECTRIFICATION.

In addition to the general economic advantages that would be gained by joint operation of the rail systems within the superpower zone by either steam or electricity, there are other advantages inherent in operation by electricity. These may be classified as advantages of electric traction in operation and advantages of the electric locomotive as a machine.

ADVANTAGES IN OPERATION.

Some of the advantages of electric operation are the conservation of national resources, both of coal and labor; an increase in the capacity of main and yard tracks; an improvement of the physical condition of terminals and an increase in the value of the property, as shown by the New York Central and Pennsylvania terminals in New York City; benefits both to the traveling public and to residents along the route through the elimination of noise and smoke, the possibility of providing multiple-level terminals and freight warehouses; and economy in operation through the use of fuel and machinery for generating energy by a few skillful operators in economical stations as contrasted with a large number of technically ignorant operators with small, uneconomical machines.

The electric locomotive is equipped with meters that afford complete knowledge and control of operating conditions and that are also a valuable guide in handling the train, particularly in starting a long, heavy train. With electric traction the economy of the entire sequence of operation is not dependent upon one man, as it is with steam. Operation is therefore no longer a matter of individual human judgment, skill, or fidelity. It is this unfortunate human element that nullifies the theoretical advantages of the "full-jeweled movement" steam locomotive. The effectiveness of the devices for increasing efficiency and capacity, such as brick arches, superheaters, stokers, siphons, automatic fire doors, and power reverses, necessarily depends on the intelligence and faithfulness of the average engineer, and in consequence the average results are low. The inherent wastefulness of the steam locomotive is proved by its own advocates in their claim that "40 per cent of its coal can be saved by the careful use of these auxiliary devices." Then why be skeptical of a saving of 60 per cent by a modern power station, which has all these devices in greater completeness and, in addition, has brains to use them?

The speed of different classes of trains will be more nearly uniform. Much heavier trains can be handled, and at the same time light freight trains can be moved at the speed of local passenger trains. It has been proved that for the heaviest freight service, such as mountain-grade work, the electric locomotive is superior to the steam locomotive, but its superiority in handling light freight at high speed is not so generally understood.

As the electric locomotive is simple and as all locomotives of a given class are identical and no more skill is required to operate them than is demanded of an ordinary chauffeur, all locomotives will be pooled, so that the total number required will be materially reduced.

A considerable saving in time and hence an increase in capacity will be made by lengthening the operating divisions, which will be from 200 to 400 miles long instead of 100 miles. An electric passenger locomotive will run in the morning from New York to Boston and will return in the afternoon or at night, making a total run of 450 miles a day. A similar round trip will be made between New York and Washington, or New York and Syracuse. The electric locomotive can be kept at work on the road for 20 hours a day, and if operated at an average speed of 25 miles an hour can run 500 miles a day. This mileage, however, is double that of the electric passenger engines now used on the New Haven line and is higher than would be obtained as an average, but there is every reason to believe that with unified operation an average between 250 and 500 miles can be made.

The flexibility of the electric locomotive is much greater than that of the steam locomotive. Its capacity is determined by heating and therefore by the average work it has to do, and not by the maximum grade, which is taken care of by the overload capacity of the engine. With electric traction the maximum grade for the profiles within the superpower zone is practically eliminated as the determining factor in locomotive equipment.

The availability of the electric locomotive for service is at least twice as great as that of the steam locomotive. After a trip it can be thoroughly inspected in less than an hour, whereas the thorough inspection of a heavy steam locomotive consumes four to ten hours. It requires no water, fuel stations, ashpits, or turntables. The repair-shop capacity required is less than a third of that needed for steam locomotives. The expense of track maintenance is reduced, and the ballast is cleaner. The engine-house expense is reduced nearly to a negligible amount. In the electric locomotive energy can be regenerated where the profile permits it, thus saving some energy and much wear of brake shoes, bettering the handling of trains, and consequently saving expense in freight-car maintenance.

As a result of these and other advantages the electric locomotive should, under favorable conditions, handle twice as many ton-miles as the steam locomotive per locomotive-year; on the Norfolk & Western it actually handles three times as many ton-miles. This gain is not possible under all conditions, but it is possible where the traffic is great and the tracks, yards, and terminals are congested, as they are in the superpower zone.

Electric traction, then, gives increased capacity of main track, yard track, and locomotives with reduced cost of operation and maintenance per ton-mile and per passenger-mile.

ADVANTAGES OF THE ELECTRIC LOCOMOTIVE AS A MACHINE.

The electric locomotive is a better machine than the steam locomotive for the following among other reasons: It has no boilers or firebox; it has a shorter rigid wheel base; it carries no tender; it has a greater ratio of weight on drivers to total engine weight; it has less weight per driving axle, and a greater proportion of its weight is spring borne; it has uniform torque and therefore a higher coefficient of adhesion; it can be built for any power desired by increasing the number of driving axles and is therefore free from limitations of length; its maximum torque is available at much higher speed; the steam locomotive can work to an adhesion of 20 per cent up to only 10 or 12 miles an hour, whereas the electric locomotive can work to this adhesion up to 20 to 25 miles an hour; its efficiency over a range of load from 50 to 100 per cent varies only a few per cent and is constant throughout its life, whereas the efficiency of the steam locomotive varies over a wide range with age and use—a modern superheated steam locomotive requires 50 per cent more steam per horsepower-hour at full load than at half load; and finally, a steam locomotive must burn coal in descending a grade on which an electric locomotive will regenerate energy. To sum up, the electric locomotive is much the better transportation tool.

CLASSES OF ELECTRIC LOCOMOTIVES.

The great variety in types and weights of steam locomotives for freight, passenger, and switcher service is largely the result of growth, of change in fashion, and of whims of individual operating officers. There is no sound reason for such variety. The United States Railroad Administration formulated certain standard designs of steam locomotives, reducing the number

of types to about ten, including the Mallet or articulated locomotive. With electric equipment this number can be reduced still further, certainly to as few as six types and possibly to three, as may be seen from an examination of the weight on drivers of the steam locomotives now in use. Those in freight service carry between 77 and 120 tons on drivers. Of those in passenger service, 80 per cent carry between 64 and 80 tons on drivers; but a few very small locomotives, probably 5 per cent of the total, are performing no material service. Of the switchers, 90 per cent carry from 65 to 85 tons on drivers, and a few carry more.

The entire freight service in the superpower zone can be handled by electric freight locomotives having two articulated 2-axle trucks, each carrying two motors geared to the axle, the mounting being essentially the same as that in a number of locomotives now in use and similar to the usual street-car mounting. There would be two classes of locomotives of this type—a light one carrying 80 tons on drivers and having a continuous drawbar pull of 22,000 pounds at 25 miles an hour, and a heavy one carrying 110 tons on drivers and having a continuous drawbar pull of 30,000 pounds at the same speed. These units can be combined in any reasonable number; the total load on drivers can be made equal to 80, 110, 160, 190, 220 tons or as much more as may be desired, being limited only by the strength of the draft rigging. A train can of course be double-headed, and a total tractive pull up to the maximum now in use can be obtained, with at least double the present speed.

For passenger service a similar arrangement would be used—that is, two articulated 2-axle trucks, with one motor geared to each axle. The motors may be practically the same as those in the freight locomotives, the only difference being a change in gear ratio. The passenger locomotive, however, would have leading and trailing trucks, with either two or four wheels, and the total weight would be redistributed. This passenger locomotive would be of two weights, the light one having 60 tons on drivers, and the heavy one 90 tons. These also may be combined, like the freight locomotives.

For the switchers one size will be adequate, with 70 to 75 tons on drivers, of the same type as the freight locomotive. Substantially the same frame and running gear can be used, with motors of less capacity.

All three types of locomotives will have the usual overload capacity, and all will be able to operate in starting and accelerating at 25 to 30 per cent adhesion.

These suggested sizes and types of locomotives can of course be varied greatly without sacrificing the advantage of unified electric operation, but identity of types for the same service throughout the superpower zone is essential.

SCOPE OF RAILROAD INVESTIGATION.

The general purpose of this investigation is to estimate the saving that would be effected by unified electric operation of the class 1 railroads within the superpower zone and to compare this estimated saving with the investment needed to effect it.

For this purpose the traffic conditions and the kind and quantity of service assumed are those of 1919, with the substitution of the electric for the steam locomotive. Of course, to insure the greatest gain from electric traction the entire transportation scheme must be revamped and fitted to the use of the new agent. An analysis based on such a change, however, would involve a detailed study of each road, and indeed of each division, which is not now possible.

The estimated saving in the cost of operation includes a reduction in certain items of steam-railroad cost that will be effected by the change of motive power. These items, named approximately in the order of their cost, are locomotive maintenance (including engine-house service), coal and water, and wages of crew. These items make up about 90 per cent of the expense affected by the change in the method of operation. In addition to the saving on these principal items there will be some saving—an amount hard to estimate—in the maintenance of curved track and freight cars, as a result of better train handling, and in certain minor items. The reduction in all these expenses will be offset by the cost of the electric energy required to do the work done by steam, the cost of the operation and maintenance of substations and of

the electric overhead distribution system and track circuits, and the cost of maintenance of the electric locomotives.

The cost of electric energy, as the phrase is used here, means its total cost delivered to the railroad company's substation. The railroad company will have no investment in plant for generating or transmitting energy. Its investment begins with substations segregated for railroad use, owned by the railroad company individually or jointly with other companies.

This comparison of costs of investment and operation need take no account of the system of electric traction to be used except in so far as the use of different systems might entail different costs of operation or construction. The only two systems that are applicable to general traction within the superpower zone are the 3,000-volt direct-current system and the 11,000-volt (or higher) alternating-current system, both with overhead distribution circuits and rail return. Both of these systems are in successful use, and both can no doubt be designed and constructed to give satisfactory service in the zone.

The alternating-current system generally involves a lower investment cost than the direct-current system, as at low frequencies of supply substations with rotating machinery are replaced by transformers erected along the right of way; but this saving will not be effected under the super power system, for the frequency adopted for generation and transmission—60 cycles—requires substations with rotating machinery for the alternating-current as well as for the direct-current system, and the capital costs of the two are nearly equal.

The operation and maintenance of substations is ordinarily an additional burden in the direct-current system, but under the superpower system this would be offset by the addition of the frequency-changing equipment.

In order, then, to avoid some uncertain elements in the estimates of the cost of the alternating-current system it has been decided to base all estimates, both of operation and of construction, on the 3,000-volt direct-current overhead system. Substantially the same results in money could, however, be obtained with the alternating-current system, certain gains being offset by certain losses.

PROCEDURE FOLLOWED BY RAILWAY DIVISION.

The procedure of the railway division of the superpower survey in its study of the proposed electrification of the heavy-traction lines within the superpower zone comprised the collection of the physical data, the analysis of the data, and the formulation of conclusions.

DATA COLLECTED.

It was evident at the outset that it would not be adequate to study the roads as units but that a study should be made of the operating divisions of the railroads. A study of a railroad system as a whole, even if it lay entirely within the zone, would yield only average results, which might make a poor showing, whereas some of the divisions treated separately might make a good showing. It was therefore decided to ask each of the class 1 railroads within the superpower zone, of which a list is given below, to answer the questions on Form A, asking for certain fundamental data as to roadbed, equipment, and traffic. This information, like all other information sought, was to cover the year 1919.

Class 1 railroads within the superpower zone.

Boston & Maine.	Erie.
Boston & Albany.	Delaware, Lackawanna & Western.
New York, New Haven & Hartford.	Lehigh Valley.
New York Central.	Central of New Jersey.
Delaware & Hudson.	Long Island.
Ulster & Delaware.	Pennsylvania.
New York, Ontario & Western.	Philadelphia & Reading.
Lehigh & New England.	Western Maryland.
Lehigh & Hudson River.	Baltimore & Ohio.

Form A.

DATA SHEET FOR STEAM-OPERATED DIVISIONS.

BOUNDARY OF ZONE.

The zone included in the superpower survey is bounded as follows: Beginning where the 39° parallel crosses Delaware Bay, thence west to Washington, looping around Washington to include the city; thence north along the 77° meridian to its intersection with the 41° parallel; thence northeasterly to the intersection of the 43° parallel[1] and the 75° meridian; thence east to the vicinity of Portsmouth, N. H., looping around that city; and thence to the Atlantic seacoast, running outside of Long Island and New Jersey to the starting point on the 39° parallel.

The information requested herein refers to those parts of your system included within the above boundaries which are steam operated wholly or in part. (Data covering electric operations are outlined on "Data sheet for electric-operated divisions.")

ROADBED.

1. Outline map, showing all lines within the zone, indicating division points, number of main tracks, sidings, etc.; also indicate nearest division point outside of zone boundaries. Maps giving track profiles.
2. Diagram of principal yards, showing track layout.
3. Summation of mileage of track—e. g., first, second, and other main tracks; sidings, etc., for each division.

EQUIPMENT.

4. Number and classification of locomotives assigned to each division for freight, passenger, and switching service, giving for each class total weight with tender full and tender empty, and weight on drivers.

TRAFFIC.

Give separately for each division for each month of 1919, and total for the year:

5. Passenger service, train-miles, total locomotive-miles, and car-miles.
6. Freight service, train-miles and total locomotive-miles.
7. Gross ton-miles moved (including engine and tender), separately for freight and passenger.
8. Switching service, ton-miles, engine-miles, engine-hours, or in such other form as is at hand.
9. Amount of coal used for each class of service separately, if possible, and totals; kind of coal burned.
10. Average annual maintenance per locomotive-mile, separately for each class, if possible.

On January 15, 1921, all replies were in hand. A preliminary analysis was made of each set of replies when received; correspondence with the designated officer of each railroad helped to clear up points that were obscure and supplemented the information furnished; and all available data covering roadbed, equipment, and traffic were complete before the middle of February.

In addition to Form A a second sheet (Form B) was sent to the roads that were in part electrically equipped—the Baltimore & Ohio, the Pennsylvania, the Long Island, the New York Central, and the New York, New Haven & Hartford. The questions on this form are more general and were intended principally to elicit an accurate description of the physical property and equipment, together with sufficient statistics of traffic and of electric supply to permit their discriminating use in the allocation of energy required for the proposed unified operation of the steam roads. This information was all in hand at about the same time as the data from the steam roads.

Form B.

DATA SHEET FOR ELECTRIC-OPERATED DIVISIONS.

BOUNDARY OF ZONE.

The zone included in the superpower survey is bounded as follows: Beginning where the 39° parallel crosses Delaware Bay, thence west to Washington, looping around Washington to include the city; thence north along the 77° meridian to its intersection with the 41° parallel; thence northeasterly to the intersection of the 43° parallel and the 75° meridian; thence east to the vicinity of Portsmouth, N. H., looping around that city; and thence to the Atlantic seacoast, running outside of Long Island and New Jersey to the starting point on the 39° parallel.

The information requested herein refers to those parts of your system included within the above boundaries which are electrically operated wholly or in part. (Data covering all steam operations are outlined on "Data sheet for steam-operated divisions.")

[1] The northern boundary of the zone as finally studied is the 44th parallel.

DESCRIPTION OF PHYSICAL PROPERTY.

1. A map showing the electric divisions, indicating tracks electrified and location of power house and substations, and track profiles.

2. A description of the system of generation, transmission, transformation, distribution, and utilization of the electric supply, including general equipment of power stations, substations, etc. Diagrams giving feeder, trolley (or third rail), and bonding layouts, and any printed descriptions or references thereto.

3. General description with drawings of locomotives in use, with total weight and weight on drivers.

4. Characteristic performance curves of locomotives—speed, torque, and heating.

TRAFFIC STATISTICS MONTHLY FOR 1919 AND TOTALS.

5. Train-miles (excluding multiple-unit cars) for freight and passenger, or for both.

6. Electric locomotive-miles for freight and passenger, or for both.

7. Multiple-unit car mileage and train mileage.

8. Statement of switching service in electric locomotive-miles, locomotive-hours, or in such form as is at hand.

9. Total gross ton-miles moved.

ELECTRIC SUPPLY.

10. Kilowatt-hours used—power-house output or substation input or output, preferably the latter. State point of measurement and whether record is available at either of the other points, even if for shorter periods.

11. Average daily, monthly, and annual load factors, stating how divisor is determined—that is, whether hourly peak or other.

12. Monthly peak, kilowatts.

13. Cost of electric supply in detail, if generated; or price, if purchased.

14. Cost of handling traffic per train-mile and per ton-mile.

15. Maintenance cost of locomotives per locomotive-mile and annual totals.

16. Cost of construction and equipment, subdivided into energy supply, transmission system, substations, distribution, and locomotives, with date of purchase.

17. Total cost of operation and maintenance of electric system under standard Interstate Commerce Commission classification.

Tables 8, 9, 10, and 11 set forth these fundamental data of the roadbed, equipment, and traffic of each of the steam roads within the zone, and Table 12 summarizes them for the entire zone. The Central New England is included with the New Haven road in all tables.

TABLE 8.—*Steam-operated tracks owned by class 1 railroads within superpower zone, 1919, in miles.*

System.	Main track.				Yards and sidings.	Total.
	First.	Second.	Other.	Total.		
Boston & Maine	1,872	620	10	2,502	1,124	3,626
Boston & Albany	393	220	110	723	419	1,142
New York, New Haven & Hartford and Central New England [a]	2,212	819	66	3,097	1,558	4,655
New York Central [a]	790	594	414	1,798	952	2,750
Delaware & Hudson	377	233	56	666	337	1,003
Ulster & Delaware	129	.....	.....	129	34	163
New York, Ontario & Western	180	154	.....	334	118	452
Lehigh & New England	238	4	.....	242	114	356
Lehigh & Hudson River	75	.....	.....	75	57	132
Erie	715	364	67	1,146	725	1,871
Delaware, Lackawanna & Western	590	357	122	1,069	705	1,774
Lehigh Valley	673	312	129	1,114	774	1,888
Central of New Jersey	638	252	80	970	822	1,792
Long Island [a]	312	102	7	421	281	702
Pennsylvania [a]	2,176	944	515	3,635	2,473	6,108
Philadelphia & Reading	1,581	627	157	2,365	1,375	3,740
Western Maryland	95	20	.....	115	58	173
Baltimore & Ohio	350	227	43	620	307	927
	13,396	5,849	1,776	21,021	12,233	33,254

[a] Electrified track omitted.

TABLE 9.—*Steam locomotives in service on class 1 railroads within superpower zone, 1919.*

System.	Freight.	Passenger.	Switching.	Total.
Boston & Maine	465	305	203	973
Boston & Albany	147	143	61	351
New York, New Haven & Hartford and Central New England	416	407	344	1,167
New York Central	244	191	212	647
Delaware & Hudson	262	34	18	314
Ulster & Delaware	17	8	3	28
New York, Ontario & Western	77	39	8	124
Lehigh & New England	35	2	24	61
Lehigh & Hudson River	40	5	3	48
Erie	260	176	132	568
Delaware, Lackawanna & Western	312	128	130	570
Lehigh Valley	280	85	254	619
Central of New Jersey	253	155	177	585
Long Island	43	67	36	146
Pennsylvania	674	593	568	1,835
Philadelphia & Reading	474	242	366	1,082
Western Maryland	46	26	21	93
Baltimore & Ohio	106	63	141	310
	4,151	2,669	2,701	9,521
Per cent	43.6	28.0	28.4	100

TABLE 10.—*Steam traffic movement on class 1 railroads within superpower zone, 1919.*

System.	Freight, trailing load (thousands of ton-miles).	Passenger (thousands of train-miles).	Switching (thousands of locomotive-miles).
Boston & Maine	6,660,000	9,220	4,460
Boston & Albany	3,266,000	3,640	2,330
New York, New Haven & Hartford and Central New England	8,183,000	11,250	4,900
New York Central	10,914,000	10,400	5,086
Delaware & Hudson	5,650,000	910	1,143
Ulster & Delaware	85,000	240	27
New York, Ontario & Western	915,000	865	300
Lehigh & New England	488,000	30	540
Lehigh & Hudson River	710,000	125	80
Erie	5,707,000	4,600	2,306
Delaware, Lackawanna & Western	6,200,000	4,100	3,200
Lehigh Valley	5,093,000	2,170	3,480
Central of New Jersey	4,400,000	3,810	3,000
Long Island	299,000	2,500	1,200
Pennsylvania	22,545,000	23,426	14,024
Philadelphia & Reading	10,900,000	7,550	7,763
Western Maryland	235,000	240	120
Baltimore & Ohio	3,379,000	2,950	2,577
	95,629,000	88,026	56,536

TABLE 11.—*Coal used by steam locomotives of class 1 railroads within the superpower zone, 1919, in short tons.*

System.	Freight.	Passenger.	Switcher.	Total.
Boston & Maine	642,500	485,000	193,500	1,321,000
Boston & Albany	397,000	246,000	83,000	726,000
New York, New Haven & Hartford and Central New England	800,000	705,000	279,000	1,784,000
New York Central	724,000	609,500	272,500	1,606,000
Delaware & Hudson	622,000	62,000	81,000	765,000
Ulster & Delaware	18,700	14,000	1,300	34,000
New York, Ontario & Western	108,300	35,000	16,000	159,300
Lehigh & New England	63,100	2,800	27,500	93,400
Lehigh & Hudson River	58,000	7,600	5,300	70,900
Erie	575,500	356,900	161,000	1,093,400
Delaware, Lackawanna & Western	900,000	300,000	200,000	1,400,000
Lehigh Valley	676,000	187,000	240,000	1,103,000
Central of New Jersey	505,700	260,400	195,400	961,500
Long Island	84,200	141,200	48,100	273,500
Pennsylvania	1,731,200	1,413,000	750,800	3,895,000
Philadelphia & Reading	1,505,100	495,100	404,500	2,404,700
Western Maryland	48,000	16,700	9,600	74,300
Baltimore & Ohio	312,500	187,800	140,000	640,300
	9,771,800	5,525,000	3,108,500	18,405,300
Per cent	53.1	30.0	16.9	100.0

TABLE 12.—*Summary of principal data for class 1 railroads within the superpower zone for 1919.*

Road	miles	13,396
Main track	do	21,021
Yards and sidings	do	12,233
All tracks	do	33,254
Freight locomotives		4,151
Passenger locomotives		2,669
Switcher locomotives		2,701
All locomotives		9,521
Freight trailing load	thousands of ton-miles	95,629,000
Passenger service	train-miles	88,026,000
Switcher service	locomotive-miles	56,536,000
Coal burned:		
Freight service	short tons	9,771,800
Passenger service	do	5,525,000
Switcher service	do	3,108,500
All services	do	18,405,300

In addition to the data from the railroads two large electric companies, the General Electric and the Westinghouse, were asked to prepare estimates of cost of substation equipment, of electric locomotives, of catenary construction, and of other electric facilities—all as of the year 1919. Similar data were also asked of the Ohio Brass Co. and one or two other companies. All made prompt and full response. After a provisional analysis of certain of these data the opinions of engineers of electric railways were sought, and their criticisms were considered in making up final estimates of cost of construction and of operation.

The locomotive-mile and the ton-mile were selected as bases for the electric comparisons, principally for the reason that locomotive maintenance is always reported "per locomotive-mile," both for steam and electric locomotives. The statistics of electric service for energy used can easily be put into any units. Form C was standardized, and the replies from the operating roads were all tabulated in this form, as shown on the following page.

Form C.

Comparison of steam and electric operation, M. & N. system, R. division.

	Freight.		Passenger.		Switcher.		All services.	
	Unit value.	Total.	Unit value.	Total.	Unit value.	Total.	Unit value.	Total.
1. Miles of road operated	.....	293	.....	293	.....	.....	.....	293
2. Miles of track operated	.....	505	.....	505	.....	221	.....	726
Steam.								
3. Average number of assigned locomotives	.....	96	.....	89	.....	60	.....	245
4. Weight on drivers.tons	100	9, 600	64	5, 700	81	4, 860	82. 3	20, 160
5. Locomotive-miles, ...thousands	.....	1, 728	.....	4, 150	.....	1, 654	.....	7, 532
6. Trailing ton-miles.do	.....	2, 433, 000	.....	.....	.....	.....	.....	.....
7. Car-miles.....do	.....	.....	.....	28, 130	.....	.....	.....	.....
8. Coal burned.....tons	.....	221, 000	.....	225, 000	.....	68, 500	.....	514, 500
9. Coal per locomotive-mile.....pounds	.....	225	.....	108	.....	83	.....	137
Electric.								
10. Kilowatt-hours (M-ton-mile basis).thousands	30	73, 000	.....	.....	.....	.....	.....	.....
11. Kilowatt-hours (locomotive-mile basis, ...thousands	42. 3	73, 000	20	83, 000	15	24, 800	24	180, 800
12. Equivalent coal...tons	.....	73, 000	.....	83, 000	.....	24, 800	.....	180, 800
13. Coal saved, per cent and tons	67	148, 000	63	142, 000	64	43, 700	65	333, 700
Unit and total cost.								
14. Cost of coal and water[a]	$5. 00	$1, 105, 000	.....	$1, 125, 000	.....	$342, 500	.....	$2, 572, 500
15. Cost of electric energy	. 01	730, 000	.....	830, 000	.....	248, 000	.....	1, 808, 000
16. Excess cost of steam	.....	375, 000	.....	295, 000	.....	94, 500	.....	764, 500
17. Locomotive maintenance, steam[b]	. 63	1, 087, 000	$0. 366	1, 519, 000	$0. 366	605, 000	$0. 426	3, 211, 000
18. Locomotive maintenance, electric[b]	. 0823	142, 200	. 0823	341, 500	. 0823	136, 100	. 0823	619, 800
19a. Maintenance of distribution system	600. 00	84, 000	.....	218, 000	400. 00	300, 000	.....	602, 000
19b. Substation operation and maintenance	. 0007	51, 000	. 0007	58, 100	. 0007	17, 400	. 0007	126, 600
20. Total cost, steam operation	.....	2, 192, 000	.....	2, 644, 000	.....	947, 500	.....	5, 783, 500
21. Total cost, electric operation	.....	1, 007, 300	.....	1, 447, 600	.....	701, 500	.....	3, 156, 400
22. Excess cost, steam operation	2, 346	1, 184, 700	2, 369	1, 196, 400	1, 113	246, 000	3, 619	2, 627, 100

[a] Includes cost of fuel and water stations. [b] Includes engine-house expense.

ANALYSIS OF DATA.

The first nine items of Form C are taken from the replies of the railroads to the questions of Form A. Items 10 and 11 cover the kilowatt-hours used.

The view here taken is that the steam locomotive is a machine doing useful work, which in freight service is represented by the gross weight of cars and contents multiplied by the distance moved—that is, the "trailing ton-miles." In this service variations in speed are of little consequence. The total tonnage movement is here referred to as "total ton-miles" or as "trailing ton-miles plus locomotive ton-miles."

The same procedure is followed in estimating the electric requirements—the electric locomotive is regarded as a machine substituted for the steam locomotive to do the same

work. This procedure, however, does not lead to a direct statement of the saving in tonnage movement due to the smaller total weight of the electric locomotive as compared with that of the steam locomotive and tender. This difference, including for freight service the weight of the loaded tender and the part of the weight of the steam locomotive that is not on drivers, can be estimated separately; it is approximately 8 to 13 per cent of the trailing ton-miles. This difference is considerable, but it is not of so great consequence as is sometimes assumed.

In passenger service the work done is that of moving the loaded cars over a certain distance at a certain speed, and in this service the speed—the time consumed—is important.

ENERGY REQUIRED FOR ELECTRIC TRACTION.

The electric energy required for the railroads is determined from the records of lines already electrified, with proper allowance for variations in the conditions of operation, and from calculations based on the profile and the alinement of the roads considered and the efficiency of their locomotive and distribution systems.

The most extensive data available for lines already electrified are those of the New Haven road, which has installed wattmeters on its locomotives, keeps records of their individual performance, and classifies these records for the several kinds of service performed. This company also keeps daily records of the energy generated at its Coscob station and of that which it buys from the United Electric Light & Power Co. and the New York Central Railroad Co. Tables have been prepared by the New Haven company showing the energy used in slow-freight, local-freight, fast-freight, passenger, and multiple-unit service.

Table 13 is a summary of the average operating results of the New Haven system for 1919, showing the input to the locomotive in kilowatt-hours per locomotive-mile, train-mile, trailing ton-mile, total ton-mile (including locomotive), and car-mile for fast, slow, local, and all freight service; for express, local, and all passenger service; and for multiple-unit service. These figures can be used with confidence for railroads operating under conditions similar to those of the New Haven, which do not differ materially from those of a number of the other roads in the superpower zone, particularly along the coast. In fixing the units of energy for the different operating divisions much weight is given to the results of the New Haven service, modified as required by the profile and alinement under examination.

TABLE 13.—*Electric energy used by New Haven locomotives in 1919, in kilowatt-hours of locomotive input.*

	Per locomotive-mile.	Per train-mile.	Per 1,000 ton-miles.		Per car-mile.
			Trailing.	Train.	
Freight service:					
Fast	26.0	27.0	24.5	22.2	0.88
Slow	34.0	42.7	24.9	23.1	.93
Local	36.1	36.5	42.5	38.2	1.52
Average	33.6	40.0	26.6	24.5	.98
Passenger service:					
Express	13.7	24.6	44.3	32.6	2.96
Local	17.5	26.1	76.5	51.4	3.93
Average	14.7	25.1	51.4	37.0	3.21
Multiple-unit service	.....	17.4	62.2	62.2	4.2
Yard switching	12.4	.....	.....	.....	.....

Other records of electric energy for locomotive-drawn trains, both freight and passenger, are given in Table 14. The figures for the New Haven system in this table are referred to the substation output, an efficiency of 90 per cent being used for the distribution system. Those for the Chicago, Milwaukee & St. Paul are given on the authority of the electrical engineer of that road for the energy delivered to the substation, multiplied by 83 per cent as average

substation efficiency; those for the New York Central Railroad were presented by the chief engineer of electric traction at the joint meeting of the American Institute of Electrical Engineers and the American Association of Mechanical Engineers October 22, 1920; those for the Pennsylvania Terminal are given in reports made to the superpower survey. All are reduced in Table 14 to the same point of reference—the substation output.

TABLE 14.—*Electric energy used for locomotive-drawn freight and passenger trains, in kilowatt-hours of substation output.*

	New Haven.[a]	Chicago, Milwaukee & St. Paul.[b]	New York Central.	Pennsylvania Terminal.
Freight service:				
Per train-mile	44	.....	.....	.....
Per locomotive-mile	37	.....	.....	.....
Per thousand ton-miles (trailing)	29	33	.....	.....
Per thousand ton-miles (total)	27	29	.....	.....
Passenger service:				
Per train-mile	28	.....	30	.....
Per locomotive-mile	16	.....	.....	32
Per thousand ton-miles (trailing)	57	47	c 40, d 26	55
Per thousand ton-miles (total)	41	33	.....	.....

[a] Energy at locomotive 1.17. [b] Substation input 0.83. [c] Average. [d] Minimum.

The second method of determining electric energy required consists in calculating, from profile and alinement, the work due to normal train resistance and adding to this the net work done against gravity, plus the work due to curvature, plus the work due to acceleration. For example, on the profile shown in figure 13, for eastbound movement it is assumed that no power is required to descend the 0.6 per cent grade, but no credit is taken for use of the kinetic energy accumulated at the bottom of this grade in ascending the next grade; for westbound movement it is assumed that no power is required on the 0.3 per cent grade for freight service, but that the difference between 0.3 and 0.5 per cent is used for passenger service. The lifting work is taken as the sum of the separate lifts; the work against curvature is the sum of the products of degrees of curvature taken from the alinement charts, multiplied by length of curve, and the unit resistance is taken at 0.8 pound per ton per degree. In freight service an acceleration from rest to 25 miles an hour and another from 10 to 25 miles an hour is assumed for each 10 miles. The sum of these elements gives the total work required at the rail to move a ton over the division considered. This process is carried through for movement in both directions, and the average of the two results is taken for the work required. This average divided by the efficiency from rail to substation input gives the watt-hours per ton-mile measured at the substation. For divisions on which the traffic is greatly unbalanced separate estimates were made for the eastbound and westbound movements.

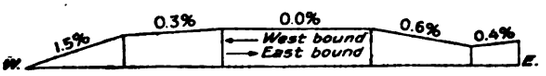


FIGURE 13.—Typical railroad profile.

Calculations made for a number of the operating divisions within the zone that differ most widely in grade and alinement show that the added resistance in freight service due to grade, curvature, and acceleration ranges from 0.5 to 10 pounds per ton. The maximum figure is that for the Jefferson division of the Erie, which includes a straight climb over a divide in both directions.

SWITCHER SERVICE.

The data of coal burned or energy required in switcher service are meager, consisting mainly of the results of a few tests recently made by the General Electric Co., of tests made by the Chicago Smoke Abatement Commission, and of tests made on the New Haven road. These tests show conclusively that the waste of coal in switcher service is great and that the actual work done by a switcher locomotive is small.

The tests in Chicago were made at a number of busy yards, in heavy service, chosen as typical of the conditions there. The average results are as follows:

Work done per locomotive-hour:		
Trailing	ton-miles	1,000
Total	do	1,400
Coal used per locomotive-hour	pounds	824
Mileage per locomotive-hour		3.26
Trailing load	tons	306
Coal per trailing ton-mile	pounds	0.824
Coal per locomotive-mile, actual	do	255
Coal per locomotive-mile, 6-mile basis[1]	do	138
Time in motion, per movement	seconds	80
Time of stop, per movement	do	53
Total time, per movement	do	133
Length of run, per movement	feet	640

From these data the following deductions are made:

Average speed when moving	miles per hour	5.45
Maximum speed (say)	do	10
Energy required at rail for acceleration per movement	watt-hours per ton	2.5
	watt-hours per ton-mile	21
Energy required at rail for train resistance	do	16
Total energy at rail	do	37
Total energy per locomotive-hour	kilowatt-hours	52
Coal burned per kilowatt-hour of work at rail	pounds	16
Efficiency assumed, rail to substation	per cent	63
Energy required for substation input, per locomotive-hour	kilowatt-hours	83

The tests made at Erie by the General Electric Co. with a storage-battery locomotive weighing 43 tons on drivers gave an average of 50 watt-hours per ton-mile of total train weight (including locomotive); the range from the six days' tests was from 47.8 to 55.7 watt-hours. Similar tests with a steam switcher weighing 40 tons on drivers gave 1.47 pounds of coal per total ton-mile. That is, in similar service the coal equivalent of 1 kilowatt-hour input to motors was 29 pounds, and that of 1 kilowatt-hour at rails was 34 pounds. The corresponding figure for road service, given below, is 7.5 pounds. Switcher service involves a great waste of coal due to large stand-by losses.

This 50 watt-hours per ton-mile is measured on the locomotive; referred to substation input it becomes 65 watt-hours per total ton-mile and 87 watt-hours per trailing ton-mile where 25 per cent of the total train weight is in the locomotive. This is practically the same as the 83 watt-hours per trailing ton-mile (83 kilowatt-hours per locomotive-hour) deduced above from the Chicago tests.

The above figures are all in general accord with such data as have been published; some results, however, have indicated much lower figures—as low as 30 to 50 kilowatt-hours at the substation per locomotive-hour.

COAL SAVED.

The quantity of coal burned in a steam locomotive equivalent in work done to 1 kilowatt-hour delivered to an electric locomotive is estimated by the electrical engineer of the Baltimore & Ohio Railroad at 7.5 pounds and by the electrical engineer of the Chicago, Milwaukee & St. Paul Railway at 8.4 pounds. A committee of the American Electrical Railway Association has published data for a modern Mallet locomotive, with superheater, which makes the equivalent coal per kilowatt-hour with stand-by losses 7.5 pounds. The same authority elsewhere gives 6.5 pounds as the equivalent of 1 kilowatt-hour at the power station, equal to 8.1 pounds per kilowatt-hour at the locomotive. Other electrical authorities give materially larger figures—some as much as 12 pounds. The weight of expert opinion is, then, that not less than 7.5 pounds of coal is required to do the work of 1 kilowatt-hour at the locomotive.

The approximate uniformity shown on the operating sheets (Form C) in the percentages of coal saved in the three services on the several roads by electric operation tends to confirm the validity of the figures taken for kilowatt-hours used (items 10 and 11, Form C); on the

[1] A standard method of expressing switching units is at 6 miles per locomotive-hour.

assumption that all the roads in the territory are fairly well operated there should be approximately the same percentage of saving of coal on each road in freight, passenger, and switcher service, respectively. The performance of individual steam locomotives of course differs materially, but that of groups only slightly. The operating sheets show that the coal saved in freight service is from 50 to 70 per cent. For passenger service the saving is from 65 to 75 per cent, in general somewhat higher than for freight service, as would be expected, inasmuch as the freight locomotives are more closely proportioned to their work than passenger locomotives. Similarly the saving in switcher service is from 70 to 85 per cent, and this also is consistent, inasmuch as the switchers operate under the worst conditions.

EFFICIENCY.

The power and the losses in the several parts of the direct-current system from substation input to rail for average load are taken as—

	Per cent.
Substation input	100
Substation output	85
Distribution efficiency	90
Input to locomotive	76.5
Efficiency of locomotive	82.5
Output of locomotive	63

Under these conditions a freight train with a resistance of 6 pounds per ton would require 19 watt-hours per ton-mile, and a passenger train at 10 pounds per ton would require 32 watt-hours per ton-mile.

EQUIVALENT COAL.

Item 12 on Form C, "equivalent coal," is uniformly taken at 2 pounds per kilowatt-hour for energy delivered at the substation. All losses of energy in transmission and conversion from the power station to the substation are included in this figure. If 1.5 pounds per kilowatt-hour is the average for coal used in superpower stations, then the assumption of 2 pounds per kilowatt-hour at the substation means an efficiency of only 75 per cent from substation input to power house. This is low—80 to 85 per cent is more nearly correct. The "equivalent" coal is given only to show the percentage of coal that would be saved under electric operation; it does not enter into the comparative costs.

COST OF COAL.

Item 14 covers the total estimated cost of coal at the railroad's fuel stations, including freight on home lines, plus the estimated cost of operating and maintaining the fuel and water stations, prorated per ton to the total coal used.

Only one or two of the replies from the railroads included freight on home lines. In this analysis the cost of delivering coal to points in the superpower zone has been determined from a base mine cost of $2.90 a ton for 1919. The cost of the coal delivered as thus determined is substantially the same as the cost reported by the railroad companies, after allowance for freight on home lines. In order to make the costs justly comparable throughout a unit price was adopted for railroad coal for each section; the cost per ton as thus fixed for the several sections of the zone is $5, $5.50, and $6 for the south, central, and north sections, respectively. These costs include the prorated cost of fuel and water stations. The uniform base mine price used affords a truer comparison of steam and electric operation than the variable figures of the railroad companies.

COST OF ELECTRIC ENERGY.

It is assumed that the railroads will purchase energy delivered at high pressure at substations on or near the railroad right of way, at the flat rate of 1 cent per kilowatt-hour. This price includes the total cost of generating and transforming electric energy and transmitting it to the railroad substations, with profit to the supplier.

No estimate is made of the maximum power required for the service, except in so far as it is involved in the determination of the substation capacity and the feeder capacity, for as

the cost of energy is figured at a flat rate per kilowatt-hour the maxima to be provided do not enter into this item.

Similarly, no definite ratio has been assigned to the eastbound and westbound traffic; in general this ratio is similar for most of the roads in the zone. Where the profiles indicate that greater work is required in one direction than in the other this difference has been taken into consideration in the allocation of energy. All estimated figures here given are assumed averages and would of course have to be modified for each division by detailed study.

The load factor of the several divisions will be between 40 and 60 per cent, and 50 to 53 per cent may be taken as the average for unified operation.

MAINTENANCE OF STEAM LOCOMOTIVES.

Item 17 of Form C is the cost of steam-locomotive maintenance as reported by the railroads, plus engine-house expense, prorated to the locomotive-mile. This item is the one affected most by electrification. The saving in maintenance by the electric locomotive is from two to five times the saving in coal; and this difference accounts for 50 to 100 per cent of the net saving made by electric traction.

Table 15 gives the cost of steam-locomotive maintenance for the principal systems in the superpower zone for 1919; the amounts included are Interstate Commerce Commission accounts No. 308, locomotive repairs, and Nos. 388 and 400, engine-house expenses for yard and train locomotives. These costs are reduced to the cost per locomotive-mile by taking as divisor the total mileage. From this result and the average weight of locomotive on drivers the sum of the cost of repairs and engine-house expense is prorated to the cost per locomotive-mile for 100 tons on drivers.

TABLE 15.—*Cost of maintenance of steam locomotives for 1919.*

System	Average weight on drivers (tons).	Distance traveled (thousands of locomotive-miles).	Interstate Commerce Commission accounts.							
			Repairs (No. 308).		Engine-house expense (Nos. 388 and 400).		Total cost.			
							Actual.		Prorated to 100 tons on drivers.	
			Per locomotive-mile (cents).	Per locomotive-year.	Per locomotive-mile (cents).	Per locomotive-year.	Per locomotive-mile (cents).	Per locomotive-year.	Per locomotive-mile (cents).	Per locomotive-year.
Boston & Maine	80.9	24,592	25.33	$5,562	8.66	$1,904	33.99	$7,466	55.63	$12,263
New York, New Haven & Hartford	63.9	23,071	29.9	6,110	11.02	2,253	40.92	8,363	64.05	13,210
Central New England	68.6	1,844	31.23	7,578	10.37	2,540	41.60	10,118	60.65	14,755
New York Central	86.5	91,313	21.15	5,203	8.55	2,103	29.70	7,306	34.28	8,433
Delaware & Hudson	89.2	11,015	32.6	7,319	12.22	1,832	44.82	9,151	50.20	10,269
Lehigh & New England	74.2	1,212	27.8	5,521	7.82	1,554	35.62	7,075	48.05	9,545
Lehigh & Hudson River	76.3	767	27.8	4,267	8.77	1,345	36.57	5,612	47.94	7,362
Erie	90.4	26,078	45.6	9,790	9.65	2,070	55.25	11,860	61.19	13,126
Delaware, Lackawanna & Western	77.9	19,263	26.9	6,836	9.45	2,401	46.35	9,237	46.62	11,855
Lehigh Valley	85.6	17,883	40.6	7,126	8.75	1,537	99.35	8,663	57.62	10,115
Central of New Jersey	72.9	12,289	29.2	6,210	6.24	1,328	41.60	7,538	48.55	10,339
Pennsylvania	83.53	112,595	38.6	9,216	6.85	1,634	45.45	10,850	54.60	12,983
Philadelphia & Reading	78.3	22,164	32.6	6,853	8.93	1,879	31.53	8,732	53.00	11,152
	80.76	364,086	31.8	7,246	8.39	1,911	40.19	9,157	49.80	11,310

Table 16 gives similar data for the New York Central, Pennsylvania, Reading, New Haven, and Erie systems for 1911 to 1919. The weighted average is given for the years 1911 to 1915, inclusive, a period during which there was practically no variation in these unit costs.

It is difficult to find a satisfactory explanation of the great variations in these figures among the different systems; the division of total cost between repairs and engine-house expense differs somewhat, certain roads throwing more of the work on the engine house; but the sum of the two items is still widely divergent. There is no difference in the kind of service to which the locomotives are put that will account for these marked variations.

TABLE 16.—*Cost of maintenance of steam locomotives for 1911–1919.*

System.	Average weight on drivers (tons).	Distance traveled (thousands of locomotive-miles).	Interstate Commerce Commission accounts.							
			Repairs (No. 308).		Engine-house expense (Nos. 388 and 400).		Total cost.			
							Actual.		Prorated to 100 tons on drivers.	
			Per locomotive-mile (cents).	Per locomotive-year.	Per locomotive-mile (cents).	Per locomotive-year.	Per locomotive-mile (cents).	Per locomotive-year.	Per locomotive-mile (cents).	Per locomotive-year.
New York Central:										
1911–1915	75.36	66,356	9.04	$2,460	3.1	$849	12.14	$3,309	16.11	$4,391
1916	82.24	108,626	7.6	2,421	3.06	972	10.66	3,393	12.96	4,126
1917	83.60	106,403	10.0	3,051	4.07	1,241	14.07	4,292	16.83	5,134
1918	85.60	100,576	17.59	4,689	7.30	1,947	24.89	6,636	29.08	7,752
1919	86.50	91,313	21.15	5,195	8.54	2,100	29.69	7,295	34.32	8,434
Pennsylvania:										
1911–1915	75.85	94,142	12.7	3,221	2.8	710	15.50	3,931	20.44	5,183
1916	83.4	105,522	13.1	3,478	2.6	687	15.70	4,165	18.82	4,994
1917	87.6	108,638	17.5	4,620	3.4	899	20.90	5,519	23.86	6,300
1918	90.4	122,965	32.88	8,960	3.7	1,784	36.58	10,744	40.46	11,885
1919	91.0	112,595	38.62	9,175	6.8	1,627	45.42	10,802	49.91	11,870
Philadelphia & Reading:										
1911–1915	62.92	24,631	11.69	2,886	3.04	750	14.73	3,636	23.41	5,779
1916	70.83	27,422	12.28	3,397	3.19	883	15.47	4,280	21.84	6,043
1917	73.20	28,126	17.85	4,993	4.14	1,156	21.99	6,149	30.04	8,400
1918	75.4	27,080	28.17	7,423	7.50	1,975	35.67	9,398	47.31	12,464
1919	78.3	22,164	32.6	6,853	8.93	1,879	41.53	8,732	53.04	11,152
New York, New Haven & Hartford:										
1911–1915	50.7	27,027	9.6	2,171	3.00	681	12.60	2,853	24.85	5,625
1916	55.6	27,495	9.98	2,272	3.61	822	13.59	3,094	24.44	5,565
1917	57.5	26,099	14.0	3,160	4.77	1,078	18.77	4,238	32.64	7,370
1918	61.4	24,784	30.85	6,400	8.99	1,861	39.84	8,261	64.88	13,454
1919	63.9	23,071	29.9	6,110	11.04	2,253	40.94	8,363	64.07	13,088
Erie:										
1911–1915	74.1	28,768	11.21	2,430	3.45	749	14.66	3,179	19.78	4,290
1916	82.3	31,621	15.65	3,765	3.90	936	19.55	4,701	23.75	5,712
1917	87.6	29,903	24.20	5,400	6.11	1,360	30.31	6,760	34.60	7,717
1918	90.0	29,316	45.3	9,950	11.75	2,582	57.05	12,532	63.39	13,924
1919	90.2	26,078	45.6	9,790	9.65	2,070	55.25	11,860	61.25	3,1481

MAINTENANCE OF ELECTRIC LOCOMOTIVES.

Item 18 of Form C, cost of maintenance of direct-current locomotives, is taken uniformly at 10 cents per locomotive-mile per 100 tons on drivers. Actual costs are shown in Table 17 for all direct-current railroads in the United States for 1919, and in Table 18 for all grouped, with the weighted average, for 1913–1919. The base cost, as stated above, is applied for each road to the same average weight on drivers as that of the steam locomotives of the road.

TABLE 17.—*Cost of maintenance of direct-current electric locomotives, 1919.*

System.	Number of locomotives.	Average weight on drivers (tons).	Distance traveled (locomotive-miles).	Cost.				
				Actual.			Prorated to 100 tons on drivers.	
				Total.	Per locomotive-mile (cents).	Per locomotive-year.	Per locomotive-mile (cents).	Per locomotive-year.
Baltimore & Ohio	8	88	214,400	$24,600	11.47	$3,076	13.02	$3,491
Butte, Anaconda & Pacific	28	81	565,600	36,700	6.49	1,312	8.01	1,619
Chicago, Milwaukee & St. Paul	46	225	2,181,200	340,200	15.59	7,394	6.93	3,286
Michigan Central	10	108	245,500	34,600	14.10	3,462	13.05	3,205
New York Central	73	92	1,940,900	124,400	6.41	1,704	7.00	1,862
Pennsylvania Terminal	31	103	1,348,000	225,300	16.71	7,266	16.30	7,088
	196	124	6,495,600	785,800	12.10	4,009	9.77	3,236

TABLE 18.—*Cost of maintenance of direct-current electric locomotives, 1913–1919.*

Year.	Total distance traveled (locomotive-miles).	Cost per locomotive-mile per 100 tons on drivers (cents).
1913	2,422,800	5.83
1914	3,678,200	5.42
1915	3,808,800	5.44
1916	5,662,600	4.50
1917	6.797,000	5.89
1918	6,431,600	7.66
1919	6,495,700	9.77

DISTRIBUTION SYSTEM.

Item 19, Form C, maintenance of the electric distribution system, is taken at $600 per mile for main track and $400 per mile for yard track. These figures are based on the operating costs of certain electric roads and on a consideration of the usual maintenance costs of works of similar construction. Although $600 per mile of main track may seem low, it is probably not low if applied to a widespread system under unified control of both inspection and maintenance.

MAINTENANCE OF SUBSTATIONS.

Item 19b, Form C, cost of operation and maintenance of substations, is based on $1.50 per kilowatt per year of capacity, giving 0.7 mill per kilowatt-hour for a capacity factor of 25 per cent. This is adequate for stations of the size required in a unified system for the entire zone.

SAVING IN WAGES OF TRAIN CREWS.

Item 22 gives the excess cost for steam service as compared with electric service without allowance for saving in crew wages. Few data are available to show the amount of such saving, but those that are available indicate that it will be considerable. In the Butte, Anaconda & Pacific freight service there has been a decrease in crew time of 29 per cent per ton-mile and a simultaneous increase in tonnage moved of 35 per cent, together equivalent to a decrease of 47 per cent in crew wages. On the Chicago, Milwaukee & St. Paul there has been an average decrease of 25 per cent in crew time and an increase of 30 per cent in tonnage moved, together equivalent to a decrease of 42 per cent in crew wages. On the Norfolk & Western two electric locomotives pull the same train as three Mallets at double the speed, making an output per locomotive-hour three times as great and a consequent saving in crew wages of 67 per cent. The reason for this reduction in crew wages per ton-mile is clear: if a steam locomotive pulls a train 100 miles in 10 hours and an electric locomotive pulls it 100 miles in 8 hours, the use of the electric locomotive will save 33 per cent in crew wages (as 2 hours of the 10 would be paid for at double-time rates); and if the train pulled by the electric locomotive is 25 per cent heavier, the saving in wages will be 46 per cent. Such a saving is easily made.

It is not yet possible to determine exactly the manner in which traffic within the superpower zone will be handled, but it is conservatively assumed that there will be an increase in ton-miles per electric locomotive-hour of 33 per cent and a consequent reduction in crew wages per ton-mile of 25 per cent.

Table 19 shows for 1919 the crew wages in freight service per thousand ton-miles for the principal systems in the zone, the tonnage moved, and the saving due to an increase of 33 per cent in output; this saving averages 10 cents per thousand ton-miles. Applied at this rate the saving on the entire freight traffic of the zone in 1919 would have been $9,560,000.

For passenger service no data are at hand; a general consideration of the subject does not indicate a material saving in crew wages, and therefore none is assumed.

In switcher service the advantages of the electric locomotive in its quicker acceleration and quicker initial start are far-reaching. Tests made by the General Electric Co. at Erie show a movement per hour for the electric switcher of 1,000 trailing ton-miles as against 250 for a steam switcher of the same weight on drivers. The experience at the Oak Point yard of the

New Haven road proves that the relative output per locomotive-hour is more than 2 to 1. In view of these facts and of the characteristics of the machines, it is estimated that the electric switcher will do 50 per cent more work per hour than the steam switcher, and that consequently the wage account for the same total service will be reduced by 33 per cent.

Table 19 shows that the average wages per switcher-mile in the superpower zone are $0.60. The saving will then be $0.20 per mile, and the total saving in wages for the entire switcher traffic in the zone in 1919 (56,536,000 miles) would have been $11,310,000; this is greater than the saving in freight service.

TABLE 19.—*Analysis of crew wages for freight and switcher service, 1919.*

System.	Freight service.			Switcher service.		
	Wages per thousand ton-miles.	Train movement (millions of ton-miles).	Saving in wages under electric operation (25 per cent).	Wages per switcher-mile.	Train movement (thousands of switcher-miles).	Saving in wages under electric operation (33 per cent).
Boston & Maine	$0.40	6,600	$660,000	.....	.....	.....
Boston & Albany	.42	3,266	343,000	.....	.....	.....
New York, New Haven & Hartford and Central New England	.55	8,183	1,130,000	$0.60	4,900	$980,000
New York Central	.27	10,914	738,000	.45	5,086	760,000
Delaware & Hudson	.35	5,650	495,000	.69	1,143	265,000
Lehigh & Hudson River	.....	.....	.....	.....	.....	.....
Erie	.29	5,707	415,000	.....	.....	.....
Delaware, Lackawanna & Western	.31	6,200	481,000	.58	3,200	620,000
Lehigh Valley	.50	5,093	635,000	.57	3,480	660,000
Central of New Jersey	.50	4,400	550,000	.57	3,000	570,000
Pennsylvania	.38	22,545	2,140,000	.61	14,024	2,850,000
Philadelphia & Reading	.49	10,900	1,330,000	.68	7,763	1,760,000
Baltimore & Ohio	.42	3,380	355,000	.....	.....	.....
	.....	92,838	9,272,000	.....	42,596	8,465,000

Average wage saving per thousand ton-miles, 10 cents; per switcher-mile, 20 cents.

CONSTRUCTION COSTS.

Form D gives the cost of electric equipment necessary to make the savings shown on Form C.

Form D.

Cost of catenary system and electric equipment, M. & N. system, R. division.

	Miles.	Cost.	
(1) Catenary system:			
(a) Single track	175	$2,013,000	
(b) Double track	68	1,700,000	
(c) Three-track	9	291,000	
(d) Four-track	42	1,625,000	
(e) Yards and sidings	221	1,658,000	
(2) Total	.....	.....	$7,287,000
(3) Substations ... kilowatts	*Capacity.* 82,100	.....	4,926,000
(4) Locomotives:	*Number.*		
(a) Freight	43	3,440,000	
(b) Passenger	55	4,576,000	
(c) Switcher	41	2,657,000	
(5) Total	139	.....	10,673,000
(6) Sum of specified items	.....	.....	22,886,000
(7) Allowance for unspecified items, 10 per cent of (6)	.....	.....	2,288,600
(8) Overhead, 20 per cent of (6)	.....	.....	4,577,200
(9) Total gross cost	.....	.....	29,751,800
(10) Credit for released steam locomotives	*Total tonnage.* 30,300	.....	[a] 6,060,000
(11) Net cost	.....	.....	23,691,800

[a] Present value.

COST OF CATENARY SYSTEM.

The estimates of cost of the overhead structure assume the use of cross-catenary construction, with guyed tubular steel poles, main and secondary steel-strand messengers, two 4/0 copper contact wires, concrete foundations for all poles, and high-strength steel strand. Rails to be single-bonded with 300,000 circular mil bond; a 4/0 copper ground wire to be carried on the pole top. Poles all to carry tops and two cross arms, each with two pins.

The estimates of cost for this structure, based on prices in 1919, are derived from detailed estimates submitted by the General Electric Co., the Westinghouse Electric & Manufacturing Co., and the Ohio Brass Co. These estimates were for single, two, three, and four track line; for tangent, 2°, 4°, 6°, and 8° curvature; for yard track; and for branch lines. The estimates of the Ohio Brass Co. in particular give the quantities and prices of all items in complete detail.

These estimates have been carefully analyzed and checked up by comparison with the estimates of the Chicago Smoke Abatement Commission's report; they have also been submitted for criticism to engineers particularly versed in work of this class.

The estimates show good general agreement. Those of the Westinghouse Co. were slightly lower than those of the General Electric Co.; those of the Ohio Brass Co. were the highest. The costs given in the Chicago report, extended to the prices in 1919, are about the same as those of the General Electric Co.

The final costs determined for the 3,000-volt system are given in Table 20, which includes all costs of labor and material for the circuit outside of the substation for an average assumed alinement. The cost of the feeders is shown separately, the figures being taken from Table 24 below. Table 21 gives unit prices and quantities.

TABLE 20.—*Estimated cost of cross-catenary construction, with guyed steel poles, for 3,000-volt direct-current system.*

Number of tracks.	Size of feeder (circular mils).	Cost.		
		Catenary structure.	Feeder.	Total.
Per mile of road.				
One	500,000	$9,300	$2,200	$11,500
Two	1,000,000	20,900	4,100	25,000
Three	1,250,000	27,000	5,300	32,300
Four	1,500,000	32,500	6,200	38,700
Five	1,500,000	38,000	6,200	44,200
Per track mile.				
Yard tracks	.....	$7,500	.....	$7,500

TABLE 21.—*Quantities and unit prices for double-track 3,000-volt direct-current cross-catenary tangent, 300-foot span.*

Item.	Unit prices.	Per mile of line.	
		Quantity.	Cost.
Steel poles, guys, etc	7 cents per pound	30 tons	$4,200
Concrete	$20 per yard	130 yards	2,600
Excavation	$2 per yard	500 yards	1,000
Contact wires	23 cents per pound	13,500 pounds	3,110
Cross span, complete	$71 per span	17.6 spans	1,250
Messenger span, complete	$55 per span	35.2 spans	1,940
Work train, crew expenses	.....	.....	600
Labor for erection (except bond)	.....	.....	2,400
Bonds, labor and material	.....	.....	1,400
Steel strand, ⅝-inch	8 cents per foot	.....	.....
Steel strand, ½-inch	3 cents per foot	.....	.....
Labor:			
Foremen	$8.00 per day	.....	.....
Linemen	$6.00 per day	.....	.....
Helpers	$4.50 per day	.....	.....

The figures given in these tables are probably high, for when construction of this magnitude is undertaken all materials will be furnished at wholesale prices and the work will be systematized as a large-scale job. Moreover, there is no doubt that a simpler design can be made, which will save weight and cost through the use of higher-grade materials for certain parts of the structure.

COST OF SUBSTATIONS.

It being impracticable to lay out load curves for the several operating divisions, the substation capacity necessary (see item 3, Form D) has been based on an analysis of existing installations. The "capacity factor"—that is, the ratio of average annual output to total equipment capacity in present railroad substations—is used as the basis for determining the capacity of the proposed railroad substations within the zone.

Table 22, compiled from data of nearly all the electrified heavy-traction roads, shows that for a total use of 486,000,000 kilowatt-hours per year on eight roads there is a total substation capacity of 248,500 kilowatts, giving a ratio of average load to rated capacity of 22 per cent. For all the roads except the Long Island this ratio is singularly uniform, being within the limits of 21 to 26 per cent.

TABLE 22.—*Average energy output of heavy-traction substations per kilowatt of capacity.*

System.	Output (millions of kilowatt-hours).	Total substation capacity (kilowatts).	Kilowatt-hours per kilowatt of capacity.
New York Central	97	45,000	2,150
Long Island	76	56,000	1,360
New Haven	85	40,000	2,130
West Jersey & Seashore	24	12,000	2,000
Pennsylvania (Philadelphia-Paoli line)	24	12,000	2,000
Chicago, Milwaukee & St. Paul:			
Rocky Mountain division	66	29,000	2,270
Missoula division	60	30,500	1,970
Pennsylvania Terminal	54	24,000	2,250
	486	248,500	Av. 1,960

Plant capacity factor, 22 per cent.

Some of these roads have a lower traffic density than those of the superpower zone, particularly than those in the vicinity of the large cities, where yard service is heavy. To make some allowance for this condition a ratio of 25 per cent is taken as applying to the entire zone. The total substation capacity for any division is then obtained by dividing the estimated kilowatt-hours required for the service by 2,200. Peak loads will be taken care of by the overload capacity of 50 per cent for two hours and 200 per cent for five minutes.

The load factor of the individual substations will range from 15 to 60 per cent; nevertheless, owing to the variation of traffic throughout the year and the diversity between the various substation loads, the capacity should be based on a factor of 25 per cent.

A consideration of the power required for maximum trains and feeder capacity for the 3,000-volt direct-current system indicates an average spacing of substations of about 20 miles. This distance will vary for the different divisions, but this factor does not influence the estimates of cost for the substation, as they are based on a unit price.

The items that make up the unit price used in the estimate are given in Table 23. This price is based on large substations, having from three to ten motor-generator sets of 2,500 kilowatts or greater. The figures are derived from estimates submitted by the General Electric Co. and the Westinghouse Co.

TABLE 23.—*Estimated cost per kilowatt of 3,000-volt direct-current substation.*

Motor-generator sets, including exciters	$30
Transformers (110-kilovolt)	8
Switchboards (two 110-kilovolt incoming lines)	10
Building	8
Freight and installation	4
	60

COST OF 3,000-VOLT DIRECT-CURRENT FEEDERS.

The size of the direct-current feeders is based on a maximum pressure drop of 20 per cent, equal to 600 volts, for a train requiring 4,800 kilowatts halfway between substations, drawing 1,000 amperes from each substation. The following assumptions are made: Running rails, 100 pounds, with 300,000 circular mil bonds; resistance per mile of track, 0.03 ohm; two 4/0 copper trolley wires.

These data give the basis for the following table, which shows the feeder capacity required under average conditions and the cost per mile for the feeders erected.

TABLE 24.—*Capacity and cost of feeders.*

	Capacity (circular mils).	Cost per mile.
Single-track	500,000	$2,200
Two-track	1,000,000	4,100
Three-track	1,250,000	5,300
Four-track	1,500,000	6,200

COST OF ELECTRIC LOCOMOTIVES.

Item 4, Form D, gives the number and cost of electric locomotives required. The number called for is based on an annual mileage of 40,000 for freight, 75,000 for passenger, and 40,000 for switcher locomotives. The cost of the electric locomotives is based on estimates made by the General Electric Co. and the Westinghouse Co. for freight, passenger, and switcher service in 1919. These estimates are stated in cost per pound for the three classes; they are substantially the same for both companies for locomotives of the same kind. The unit costs used are 40 cents per pound of total weight for freight locomotives and switchers and 45 cents for passenger locomotives, equivalent to $800 per ton on drivers for freight locomotives and switchers and $1,300 per ton on drivers for passenger locomotives. The total weight on drivers of the electric locomotives is the product of their number by the average weight on drivers of the steam locomotives on the division.

NUMBER OF ELECTRIC LOCOMOTIVES REQUIRED.

The electric service covered by the estimates is the power equivalent of the present steam service in the zone. The year 1919 is taken for comparison, as it is the latest complete calendar year before the beginning of this investigation. The number of electric locomotives required for the service should in the final analysis be determined by a study of train movements on each division. This study was impracticable in the present investigation, and therefore a shorter method had to be used. The plan followed was to determine the average number of miles per year per electric locomotive required for freight, passenger, and switcher service. This average mileage was determined by comparing the mileage records of the electric locomotives in certain operating electric systems in the United States with the mileage records of the steam locomotives in the zone. To show why the electric locomotive gives the greater mileage, a distribution of locomotive-hours for electric service was deduced from that of the present steam service by modifying it to accord with the proved fact of the greater availability of the electric locomotive. This procedure fixed the same number of miles per year in each class of service for the entire zone; conditions of unified operation are thus implied. This leads to some irregularities in the proportional number of steam and electric locomotives on certain of the smaller roads, but the figures are intended as averages, not to apply exactly to each operating division. These smaller roads will represent less than 10 per cent of the traffic.

The assignment of the same locomotive mileage to the single-track roads with low traffic density as to the divisions having denser traffic is not strictly correct; the great variation in annual mileage of the steam locomotives of these divisions reflects the differences in traffic conditions. In order to make some allowance for the light-traffic divisions the minimum number of electric locomotives for each division is fixed at 50 per cent of the corresponding number of steam locomotives, even if the number based on mileage is less than 50 per cent.

MILEAGE.

Table 25 gives the steam mileage for 1919 of the freight and passenger service on the principal systems. Table 26 gives the available statistics on annual mileage of electric locomotives; the average for freight service is approximately 40,000 miles. The only extensive system that keeps records separately for passenger service is the New Haven, with a mileage of 73,000; this mileage can be increased with complete electric operation. The New York Central and the Pennsylvania Tunnel & Terminal are operating a short-haul service which gives no opportunity to make great mileage.

TABLE 25.—*Average steam-locomotive mileage of principal systems in superpower zone, 1919.*

[Based on total number of locomotives owned.]

System.	Freight.	Passenger.
New Haven	15,200	30,500
New York Central	17,300	34,500
Delaware & Hudson	20,600	30,500
Lehigh & Hudson River	13,400	24,100
Erie	18,900	30,000
Delaware, Lackawanna & Western	22,800	39,000
Lehigh Valley	14,700	30,500
Central of New Jersey	16,600	26,200
Pennsylvania, eastern lines	19,900	42,500
Philadelphia & Reading	21,800	33,500
Baltimore & Ohio	16,600	38,000
Average	18,000	32,700

TABLE 26.—*Average annual mileage of electric locomotives.*

[Based on total number of locomotives owned.]

System.	Freight.	Passenger.	All.
New Haven	33,500	73,000	55,000
New York Central	.....	34,500	34,500
Pennsylvania (New York Terminal)	.....	39,300	39,300
Norfolk & Western	49,000	.....	49,000
Butte, Anaconda & Pacific	43,500	.....	43,500
Chicago, Milwaukee & St. Paul	.....	.....	49,000

LOCOMOTIVE-HOURS.

Records of the distribution of locomotive-hours for a number of the roads within the superpower zone are available, particularly those of the Pennsylvania, of which eight operating divisions are included within the zone; they reflect the entire range of service, from the heaviest traffic on the New York division to the light traffic of the West Jersey & Seashore and Sunbury divisions. The Pennsylvania is taken as an example of the best average operating results.

The statistics of the operations of the Pennsylvania system for 1919 within the superpower zone are given in Table 27, which sets forth the proportion of the time of all serviceable locomotives and of all assigned locomotives, in accordance with the schedule of time specified by the United States Railroad Administration in its "Operating statistics sheets." Item 1 of the table includes items 1 and 2 of the operating statistics sheets and represents the total time that locomotives are in "hands of crew," including time between termini, time waiting at termini, and time to and from engine house. From 90 to 95 per cent of this is productive time—that is, time between termini. Item 2a represents time required for cleaning fires, washing boilers, ash-pit work, inspection, running repairs, etc. Item 2b represents time spent in waiting at engine house for call to service after maintenance forces have delivered locomotive to transportation forces. All this is wasted time. Item 3 gives the total time in the engine house, the sum of 2a and 2b. Item 4 ("stored hours") represents surplus equipment for which there is no call. Item 5 shows the total serviceable hours taken both as 100 per cent and as a percentage of total assigned locomotive hours. The differences between 100 per cent and 71, 69, and 80 per cent give for the three services respectively the proportion of total time in the shops under general repairs or awaiting such repairs.

TABLE 27.—*Average distribution of locomotive-hours in 1919 on all divisions of the Pennsylvania system within the superpower zone, in per cent.*

Item.	Serviceable locomotive-hours.			Total locomotive-hours.		
	Freight.	Passenger.	Switcher.	Freight.	Passenger.	Switcher.
1. Crew-hours	47	39	61	33	27	49
2. Engine house:						
(a) Mechanical department	31	37	18	22	26	14
(b) Transportation department	17	22	18	12	15	15
3. Total engine-house time (2a+2b)	48	59	36	34	41	29
4. Stored hours	5	2	3	4	1	2
5. Total serviceable hours	100	100	100	71	69	80

The average utilization of the locomotives in the zone as a whole is not as good as on the Pennsylvania. Table 28 gives the ratio of "crew-hours" to total serviceable hours (item 1 of Table 27) for eight of the systems within the zone, with the total number of assigned locomotives. For the weighted average of all these systems the ratio of crew-hours to total serviceable hours is 37, 30, and 50 per cent for freight, passenger, and switcher locomotives, respectively, as compared with 47, 39, and 61 per cent for the Pennsylvania.

TABLE 28.—*Average distribution of locomotive-hours of representative railroads within the superpower zone, 1919.*

System.	Total number of locomotives.	Ratio of crew-hours to total serviceable hours (per cent).		
		Freight.	Passenger.	Switcher.
Pennsylvania	1,800	47	39	61
Philadelphia & Reading	1,000	49	34	52
Central of New Jersey	600	39	40	54
Delaware, Lackawanna & Western	750	39	28	51
Erie	1,450	32	25	43
New York Central	3,500	33	29	53
Lehigh Valley	1,000	27	25	38
Delaware & Hudson	500	33	24	49
Total or weighted average	10,600	37	30	50
Equivalent number of crew-hours per year	.....	3,250	2,630	4,380

A direct comparison of time is afforded by the New Haven system. Table 29 sets forth the figures for both steam and electric operation on that system for five months of 1919.

TABLE 29.—*Ratio of crew-hours to total serviceable hours under steam and electric operation of the New Haven system, 1919.*

Month.	Freight.		Passenger.		Switcher.	
	Electric.	Steam.	Electric.	Steam.	Electric.	Steam.
March	43	27	45	29	67	48
April	50	26	45	28	68	47
September	63	40	47	29	81	54
October	62	39	50	28	81	56
November	49	39	42	27	87	53
Average	54	34	46	28	77	52

Ratio of number of serviceable electric locomotives required to do the same work:
Freight, 34÷54=63 per cent.
Passenger, 28÷46=61 per cent.
Switcher, 52÷77=68 per cent.

What can be done with motive power in proportion to the service required is shown in Table 30, which gives the distribution of serviceable locomotive-hours on the Norfolk & Western. Here the locomotives are in road service 74 per cent of the total time and the crew-hours are 76 per cent. This is to be compared with 33 per cent as the average for freight service on the Pennsylvania and 28 per cent for all the roads in the zone—that is, one electric locomotive in the Norfolk & Western freight service does as much work as is done in the rest of the zone by 2.65 steam locomotives.

TABLE 30.—*Distribution of electric locomotive-hours in freight service on Norfolk & Western Railway, in per cent.*

In road service		74.0
Terminal delay in hands of crew		2.3
Engine house:		
Inspection and repairs (motive-power department)	14.8	
Waiting (transportation department)	8.9	
		23.7
Total serviceable hours		100
Recapitulation by departments:		
Transportation		85.2
Motive power		14.8

From Table 27 the figures in Table 31 are deduced, showing the estimated average distribution of locomotive-hours of electric locomotives. In this table the crew-hours for freight service are taken at 77 per cent of the corresponding figure for steam service of the Pennsylvania. This assumes that on the average an electric locomotive will yield 30 per cent more trailing ton-miles per crew-hour than the average steam locomotive—an assumption based on data of operation of several electric roads. This result is attained partly by higher speed and heavier trains, or both; in minor part by the elimination of the loaded tender and nondriver weight of the steam locomotives; and largely by standardization of locomotive types and pooling of locomotives.

In passenger service the electric crew-hour is taken as 11 per cent more productive than the steam; this result will be attained in great measure by the widespread use of multiple-unit cars for the short runs in the extensive suburban service of the zone and by better-sustained average speed for other passenger trains. The average speed of passenger trains on the Pennsylvania system is only 17.5 miles per crew-hour; a uniform increase of 11 per cent would mean an average of less than 20 miles per hour, a speed that is now exceeded by a number of steam divisions. For switcher service the electric crew-hour is taken at 1.50 times as productive as the steam. The service on the New Haven line and the General Electric Co.'s tests at Erie and Schenectady give higher ratios.

Item 2a, Table 31, showing time in engine house for repairs, etc., is taken at about one-third of the steam time. For item 2b, time awaiting call, the ratio to crew-hours is taken at approximately the same as in steam service. This estimate is moderate or perhaps low, for with half as many locomotives in service the waits must necessarily be shorter, and moreover the use of classes of uniform locomotives will save much of this delay. The ratio of serviceable to total electric locomotive-hours is pretty well established at about 90 per cent. With these assumptions, all of which tend to minimize the savings of unified electric operation, the Pennsylvania system could be operated electrically in 61, 66, and 54 per cent of the serviceable hours, or 48.5, 51, and 48 per cent of the total hours now required for the steam operation of the freight, passenger, and switcher services, respectively.

TABLE 31.—*Estimated distribution of electric locomotive-hours, in percentages of time required for steam operation of the Pennsylvania system.*

Item.	Freight.		Passenger.		Switcher.	
	Steam.	Electric.	Steam.	Electric.	Steam.	Electric.
Crew-hours	47	36	39	35	61	41
Engine house:						
a. Mechanical department	31	10	37	12	18	6
b. Transportation	17	13	22	18	18	12
Total engine house (2a+2b)	48	23	59	30	36	18
Stored	5	2	2	1	3	1
Total serviceable hours	100	61	100	66	100	60
Ratio of serviceable to total hours	71	90	69	90	80	90
Total hours of assigned locomotives	141	68	144	74	125	67

Relative number of electric locomotives required:
Freight, 68÷141=48.5 per cent.
Passenger, 74÷144=51.0 per cent.
Switcher, 67÷125=53.5 per cent.

Table 32, taken from Table 31, sums up the estimated schedule for electric operation. The crew-hours amount to 59, 53, and 76 per cent of the serviceable hours. These figures are low, in the opinion of several electric operating men, who claim that crew-hours should be taken at 70 per cent of total hours, equivalent to 78 per cent of serviceable hours.

TABLE 32.—*Distribution of electric locomotive hours.*

Item.	Freight.	Passenger.	Switcher.
Crew-hours	59	53	76
Engine house:			
(a) Mechanical department	17	18	11
(b) Transportation department	21	27	11
Total engine house	38	45	22
Stored	3	2	2
Total serviceable hours	100	100	100

From a direct comparison of the mileage of Tables 25 and 26 and the above analysis of locomotive-hours the annual mileage of electric locomotives is taken at 40,000 for freight locomotives, 75,000 for passenger locomotives, and 40,000 for switchers.

TOTAL COST.

Item 5 of Form D, the sum of items 2, 3, and 4, gives the total estimated cost of the specified items and accounts for 90 to 95 per cent of the total cost of the work. Table 33, giving the itemized costs of the Chicago terminal electrification, shows that the other items amount to less than 8 per cent. These unspecified items are principally changes in signal system, provision against electrolysis, and certain minor items. Item 7 of Form D is an allowance of 10 per cent for these unspecified costs.

TABLE 33.—*Cost of items of construction and equipment involved in the electrification of Chicago terminals, exclusive of power station and transmission system.*

Item.	2,400-volt direct-current.		11,000-volt alternating-current.	
	Total.	Per cent.	Total.	Per cent.
Substations	$5,660,000	4.0	$2,025,000	1.5
Switching stations	1,522,000	1.1	573,000	.4
Overhead contact system	33,895,000	23.8	28,142,000	20.3
Bridge warnings	1,072,000	.....	1,072,000	.....
Return circuit	6,070,000	4.3	4,446,000	3.2
Prevention of inductive effects and electrolysis	.....	.....	997,000	.....
Telephone system	272,000	.....	272,000	.....
Electric locomotives, multiple-unit equipment, work and inspection equipment	84,004,000	59.0	91,704,000	66.0
Spare parts	503,000	.....	485,000	.....
Changes in overhead structures	834,000	.....	834,000	.....
Changes in wire lines	2,028,000	.....	2,028,000	.....
Changes in signal system	6,694,000	.....	6,111,000	.....
	142,554,000	100.0	138,689,000	100.0
Summary:				
Specified items	.....	92.2	.....	91.4
Unspecified items	.....	7.8	.....	8.6
	.....	100.0	.....	100.0

ENGINEERING, CONTINGENCIES, AND INTEREST.

Item 8 of Form D covers overhead allowance of 20 per cent for engineering, contingencies, and interest. This construction will be essentially work of duplication; the units will be identical both for substation equipment and for locomotives. The estimate assumes not special production but quantity production, which will reduce the percentage required for engineering and for contingencies. Similarly, the allowance for interest should not be as great as for construction work undertaken by a single company, as the work would be done on the general credit of the combined railroad systems; money will be obtained as needed, and the construction period, during which interest must be carried, will be minimized; in fact, much of the cost represents equipment, payments for which can fairly be assumed to be made toward the end of the period of construction.

RELEASED LOCOMOTIVES.

Item 9 of Form D gives the total gross cost of electrification, which is reduced by the credit for released steam locomotives, given by item 10. This credit is based on the assumption that all steam locomotives released within the superpower zone can be used. Electrification will be progressive, and it is a reasonable assumption that locomotives as released from one division will be transferred either to another division or to another road. The amount of the credit is determined by assuming that the average condition of the locomotives is 50 per cent new, probably an underestimate in view of the fact that much of the equipment has been bought within the last ten years. The value of a new locomotive in 1919 is taken at 18 cents per pound of total weight, and the salvage value at 2 cents per pound. These figures are based on the elaborate estimates of the equipment committee of the President's Conference Committee of Steam Railroad Companies, whose reports embody the fullest examination yet made of the value and cost of steam locomotives and of their reproduction cost. From these assumptions is obtained a net value of 10 cents per pound of total weight as the amount to be credited. The average ratio of total weight to weight on drivers is found to be 1.5 for freight, passenger, and switcher locomotives, in the proportions that now prevail in the zone; this fixes the value per pound on drivers of the released steam locomotives at 15 cents.

Deduction of item 10 gives the net cost of electrification; the percentage that the saving from electric operation bears to this total cost determines whether any division is susceptible of economical electrification.

CONCLUSIONS.

The study described above has been made for all the class 1 railroad systems within the superpower zone except the Ulster & Delaware, the New York, Ontario & Western, and the Western Maryland. The first two were omitted, after a preliminary examination, because their traffic was too light to warrant electrification. The Western Maryland was omitted because only a small part of its trackage is within the zone; the preliminary examination, however, indicates that the Western Maryland traffic would justify electrification. There remained, then, 13 railroad systems[1] in the zone that were studied in accordance with Forms C and D (pp. 59, 67). In this study it was not possible to adhere strictly to the limits of every operating division reported by the railroads, and some divisions were therefore consolidated into routes. The number of divisions or routes ranged from one on the Boston & Maine to nine on the Pennsylvania and aggregated 40 for the 13 roads.

The results of the study are given in figures 14 and 15, which show for each of the 40 divisions the annual saving, in percentage of the net cost of electrification, plotted against the energy required, in kilowatt-hours per year, together with the accumulated average percentage of saving for the divisions as grouped. Figure 14 shows the saving exclusive of the saving in crew wages, and the divisions are arranged in the order of percentages. With these results as the criterion of economical electrification the "selected divisions" are assumed to be all that show a saving

[1] The Boston & Albany was included with the New York Central, and the Long Island with the Pennsylvania.

of 9 per cent or more. The group of divisions thus selected shows an average saving of 11.4 per cent. It includes 30 of the 40 divisions examined, comprised in 11 of the 13 systems shown in Plate VI. Figure 15 shows the saving including the wage saving for the 40 divisions arranged in the same order as in figure 14. For the "selected divisions" these savings range from 10.6 to 19 per cent and average 14.2 per cent. The total energy required annually for these 30 divisions will be 4,400 million kilowatt-hours, and the maximum demand approximately 850,000 kilowatts.

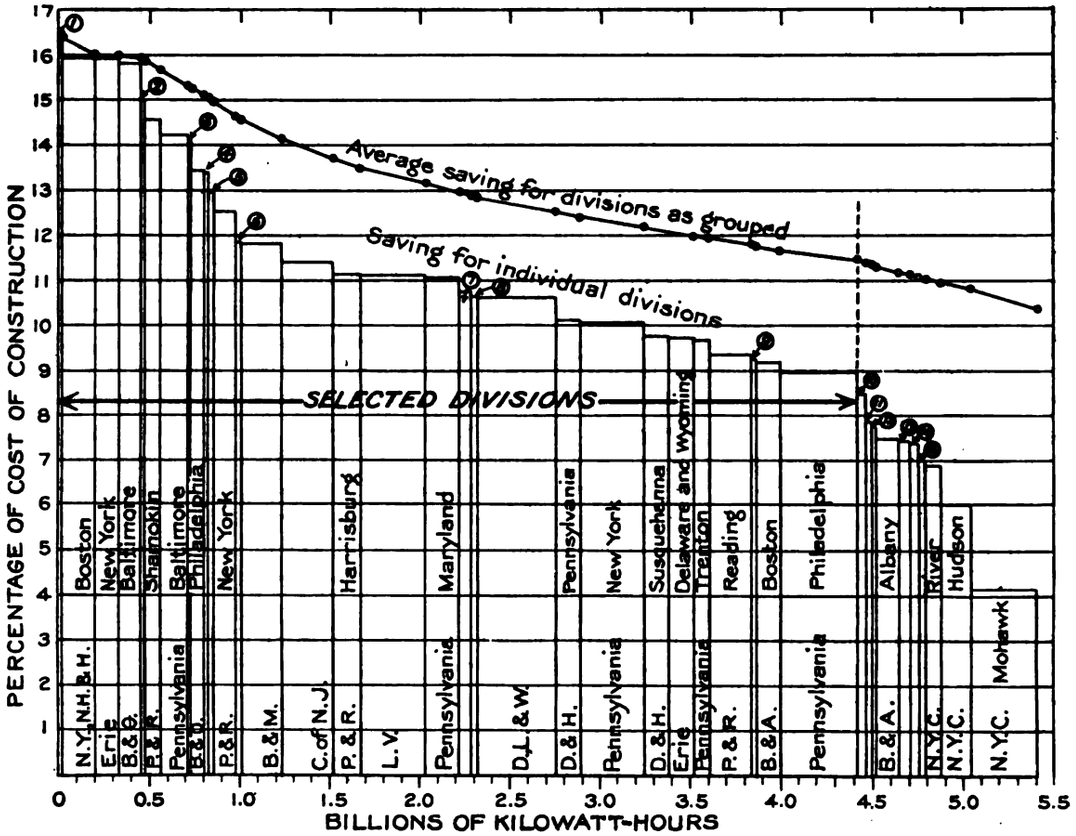


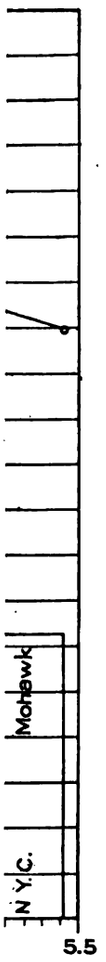
FIGURE 14.—Saving effected by electrification of heavy-traction railroads, in percentage of construction cost, not including saving in wages. Each column represents a railroad division or route. 1, New York and New Jersey division, Erie; 2, Northern division, Erie; 3, Greenwood Lake division, Erie; 4, Jefferson division, Erie; 5, Schuylkill division, Pennsylvania; 6, Springfield division, N. Y., N. H. & H.; 7, Maybrook division, N. Y., N. H. & H.; 8, Philadelphia division, P. & R.; 9, New York, Susquehanna, and Western division, Erie; 10, Cumberland Valley division, Pennsylvania; 11, Atlantic City division, P. & R.; 12, Wilmington and Columbia division, P. & R.; 13, Sunbury division, Pennsylvania; 14, New Jersey and Seashore division, Pennsylvania; 15, Lehigh & Hudson River R. R. Other divisions are indicated on the diagram.

The low percentage of saving shown by the divisions not included in the selected group, except those of the New York Central, is due to light traffic. On the New York Central the train cost of transportation, the cost of maintaining steam locomotives, and the cost of coal per mile are lower than on any other system, owing in part to the fact that this is a water-level road with a large amount of through traffic; these are favorable conditions for economical steam operation and therefore afford less opportunity for saving by electrification.

The importance of the 30 selected divisions as compared with all the divisions of class 1 railroads within the zone is shown in Table 34.

visions.

Per cent.
48
53
64
58
75
60
74
69
72



wages. Each

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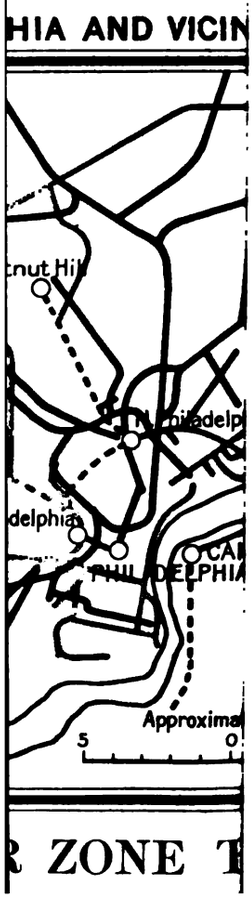


cent for the New York, Susquehanna, and Western division of the Erie to 19 per cent for the New Haven-Boston route of the New Haven.

TABLE 35.—*Summary of electric operation on selected divisions.*

System and division.	Net cost of construction.	Net reduction in annual cost of operation.			
		Including crew wages.		Excluding crew wages.	
		Amount.	Percentage of cost of construction.	Amount.	Percentage of cost of construction.
Boston & Maine	$28,862,500	$4,431,200	15.35	$3,411,200	11.82
Boston & Albany:					
Boston	18,237,700	2,071,200	11.36	1,672,700	9.17
New York, New Haven & Hartford and Central New England:					
Boston	20,300,500	3,852,500	18.98	3,235,000	15.93
Springfield	5,279,300	700,000	13.26	627,000	11.88
Maybrook	10,812,100	1,465,200	13.55	1,165,200	10.78
	36,391,900	6,017,700	16.54	5,027,200	13.81
Delaware & Hudson:					
Susquehanna	17,885,700	2,223,300	12.43	1,742,700	9.75
Pennsylvania	12,719,900	1,600,500	12.58	1,287,500	10.10
	30,605,600	3,823,800	12.49	3,030,200	9.90
Erie:					
New York (main)	19,597,100	3,655,600	18.65	3,119,100	15.92
Greenwood Lake	3,268,600	466,060	14.26	459,800	14.07
Northern	1,891,000	285,000	15.07	284,000	15.02
New York and New Jersey	1,856,400	304,675	16.42	303,800	16.37
Delaware and Wyoming	16,295,700	1,926,200	11.82	1,582,500	9.72
Jefferson	2,987,900	441,300	14.77	400,400	13.40
New York, Susquehanna, and Western	7,372,300	784,900	10.65	682,200	9.25
	53,269,000	7,863,735	14.76	6,831,800	12.82
Delaware, Lackawanna & Western	50,780,700	6,654,500	13.10	5,394,500	10.62
Lehigh Valley	45,884,800	6,310,700	13.75	5,105,200	11.13
Central of New Jersey	31,997,800	4,711,300	14.72	3,651,300	11.41
Pennsylvania:					
New York	46,494,100	6,207,300	13.35	4,677,700	10.06
Trenton	14,734,300	1,780,300	12.08	1,425,300	9.67
Philadelphia	45,597,800	5,562,400	12.20	4,074,000	8.93
Schuylkill	6,097,500	883,400	14.49	790,300	12.96
Maryland	23,691,800	3,201,200	13.51	2,627,100	11.09
Baltimore	23,673,900	3,953,300	16.70	3,364,900	14.21
	160,289,400	21,587,900	13.47	16,959,300	10.58
Philadelphia & Reading:					
New York	16,913,100	2,407,500	14.23	2,118,800	12.53
Philadelphia	7,682,000	1,299,800	16.92	814,800	10.61
Reading	29,540,200	3,640,100	12.32	2,756,100	9.33
Shamokin	15,981,900	2,734,700	17.11	2,322,700	14.53
Harrisburg	15,151,500	2,194,400	14.48	1,690,400	11.16
	85,268,700	12,276,500	14.40	9,702,800	11.38
Baltimore & Ohio:					
Philadelphia	18,821,100	3,579,000	19.01	2,979,700	13.43
Baltimore	9,675,800	1,553,400	16.05	1,299,400	15.83
	28,496,900	5,132,400	18.01	4,279,100	15.02
Grand total	570,085,000	80,880,935	14.19	65,065,300	11.41

The data of roadbed, equipment, and operation, both for steam and for electricity, of the selected divisions are summarized in Tables 36 to 42.

TABLE 36.—*Track mileage of selected divisions.*

System.	Road.	Main.	Yard.	Total.
Boston & Maine	278	504	295	799
Boston & Albany	201	368	228	596
New York, New Haven & Hartford	329	720	495	1,215
Delaware & Hudson	377	666	337	1,003
Erie	715	1,146	725	1,871
Delaware, Lackawanna & Western	551	1,030	682	1,712
Lehigh Valley	544	985	751	1,736
Central of New Jersey	315	597	658	1,255
Pennsylvania	1,503	2,733	2,107	4,840
Philadelphia & Reading	1,231	1,927	1,246	3,173
Baltimore & Ohio	351	620	307	927
	6,395	11,296	7,831	19,127

TABLE 37.—*Data of steam operation on selected divisions.*

System.	Total.			Per mile of road.				
					Traffic (locomotive-miles).			
	Locomotives.	Traffic (thousands of locomotive-miles).	Coal (thousands of tons).	Locomotives.	Freight.	Passenger.	Sum.	Total.[a]
Boston & Maine	363	9,250	630	1.31	16,730	5,750	22,480	33,270
Boston & Albany	192	5,550	365	.95	7,110	13,830	20,945	27,610
New York, New Haven & Hartford	456	11,295	825	1.39	12,770	13,900	26,680	34,340
Delaware & Hudson	314	6,940	765	.83	12,900	2,470	15,380	18,410
Erie	568	11,346	1,093	.79	6,140	6,510	12,650	15,870
Delaware, Lackawanna & Western	570	13,900	1,400	1.03	11,250	8,170	19,420	25,230
Lehigh Valley	619	10,550	1,103	1.14	8,470	4,520	13,000	19,390
Central of New Jersey	535	10,000	860	1.70	12,700	9,520	22,220	31,750
Pennsylvania	1,655	48,039	3,433	1.10	8,360	14,750	23,110	31,960
Philadelphia & Reading	960	22,353	2,200	.78	7,380	4,270	12,460	18,160
Baltimore & Ohio	310	8,122	640	.88	7,170	8,620	15,800	23,140
Total or weighted average	6,542	156,345	13,313	1.023	9,150	8,590	17,740	24,450

System.	Per mile of road.		Per mile of all track.			Road locomotive-miles per mile of main track.	Switcher locomotive-miles per mile of yard track.
	Coal (tons).	Gross freight traffic (thousands of ton-miles).	Locomotives.	Total traffic (locomotive-miles).[a]	Coal (tons).		
Boston & Maine	2,266	15,100	0.455	11,580	789	12,400	10,170
Boston & Albany	1,816	6,490	.322	9,310	612	11,430	5,880
New York, New Haven & Hartford	2,507	14,800	.375	9,300	679	12,190	5,090
Delaware & Hudson	2,030	15,000	.313	6,920	762	8,710	3,390
Erie	1,530	8,000	.303	6,060	584	7,890	3,180
Delaware, Lackawanna & Western	2,540	11,300	.332	8,120	818	10,400	4,690
Lehigh Valley	2,030	9,400	.356	6,080	635	7,180	4,630
Central of New Jersey	2,730	14,600	.426	7,970	685	11,720	4,560
Pennsylvania	2,284	13,090	.342	9,920	709	10,430	6,310
Philadelphia & Reading	1,790	9,500	.302	7,050	693	7,960	5,630
Baltimore & Ohio	1,820	9,600	.334	8,760	691	8,940	8,390
Total or weighted average	2,082	11,320	.342	8,170	696	10,040	5,480

[a] Includes switcher locomotive-miles.

TABLE 38.—*Data of electric operation on selected divisions.*

System.	Total.			Per mile of road.			Per mile of all track.		
		Substations.			Substations.			Substations.	
	Number of locomotives.	Capacity (thousands of kilowatts).	Energy required annually (millions of kilowatt-hours).	Number of locomotives.	Capacity (kilowatts).	Energy required annually (thousands of kilowatt-hours).	Number of locomotives.	Capacity (kilowatts).	Energy required annually (thousands of kilowatt-hours).
Boston & Maine	212	102	224	0.763	367	806	0.265	128	280
Boston & Albany	107	59	129	.532	294	642	.180	99	216
New York, New Haven & Hartford	233	120	297	.708	366	903	.192	99	245
Delaware & Hudson	163	125	276	.432	333	731	.163	125	275
Erie	313	156	340	.438	218	475	.167	83	182
Delaware, Lackawanna & Western	295	197	433	.535	358	785	.172	115	253
Lehigh Valley	236	168	367	.434	307	674	.136	96	211
Central of New Jersey	215	130	289	.683	414	917	.171	104	230
Pennsylvania	959	561	1,232	.638	373	820	.198	116	255
Philadelphia & Reading	488	289	635	.396	235	516	.153	91	200
Baltimore & Ohio	172	91	201	.490	260	571	.186	99	216
Total or weighted average	3,393	1,998	4,423	.531	312	692	.177	104.4	231

TABLE 39.—*Coal saved by electric operation on selected divisions.*

System.	Quantity (thousands of tons).				Percentage of steam locomotive coal.			
	Freight.	Passenger.	Switcher.	All.	Freight.	Passenger.	Switcher.	All.
Boston & Maine	253	48	105	406	63.3	60.0	70.0	64.4
Boston & Albany	93	105	38	236	60.8	65.5	73.7	64.7
New York, New Haven & Hartford	247	176	105	528	61.3	62.8	73.6	64.0
Delaware & Hudson	382	43	64	489	61.4	70.0	78.9	64.0
Erie	363	258	133	754	62.9	72.4	82.7	63.9
Delaware, Lackawanna & Western	590	225	152	967	65.6	75.0	76.0	69.1
Lehigh Valley	422	126	188	736	62.4	67.5	78.3	66.7
Central of New Jersey	276	140	155	571	60.0	70.0	77.5	66.4
Pennsylvania	887	804	509	2,200	60.0	64.5	71.8	64.1
Philadelphia & Reading	1,035	264	265	1,564	71.6	67.9	72.7	71.1
Baltimore & Ohio	211	128	101	440	67.6	67.8	72.4	68.7
Total or weighted average	4,758	2,317	1,815	8,890	64.1	67.2	74.4	66.8
Percentage	54	26	20	100	.....	.....	.....	.....

TABLE 40.—*Energy required for electric operation on selected divisions, in thousands of kilowatt-hours.*

System.	Freight.	Passenger.	Switcher.	All.
Boston & Maine	147,000	32,000	45,000	224,000
Boston & Albany	60,000	55,600	13,400	129,000
New York, New Haven & Hartford	155,500	103,800	37,800	297,100
Delaware & Hudson	240,000	18,600	17,100	275,700
Erie	213,400	98,600	27,800	339,800
Delaware, Lackawanna & Western	310,000	75,000	48,000	433,000
Lehigh Valley	254,000	60,600	52,200	366,800
Central of New Jersey	184,000	60,000	45,000	289,000
Pennsylvania	590,200	443,200	199,600	1,233,000
Philadelphia & Reading	410,900	125,100	99,300	635,300
Baltimore & Ohio	101,400	60,500	38,700	200,600
	2,666,400	1,133,000	623,900	4,423,300
Percentage	60.30	25.60	14.10	100.00

TABLE 41.—*Cost of electric track facilities and equipment of selected divisions, in thousands of dollars.*

System.	Mileage.		Specified items.			
	Road.	All track.	Track distribution system.	Sub-stations.	Loco-motives.	Sum.
Boston & Maine	278	799	8,397	6,120	14,208	28,725
Boston & Albany	201	596	5,917	3,540	7,972	17,429
New York, New Haven & Hartford	329	1,215	12,352	7,218	16,233	35,803
Delaware & Hudson	377	1,003	10,451	7,524	12,737	30,712
Erie	715	1,871	19,032	9,360	23,338	51,730
Delaware, Lackawanna & Western	551	1,712	17,131	11,820	20,388	49,339
Lehigh Valley	544	1,736	17,002	10,020	20,074	47,096
Central of New Jersey	315	1,255	11,834	7,824	14,048	33,706
Pennsylvania	1,503	4,840	46,555	33,612	75,871	156,038
Philadelphia & Reading	1,231	3,173	31,870	17,340	34,489	83,699
Baltimore & Ohio	351	927	9,695	5,484	12,634	27,813
	6,395	19,127	190,236	119,862	251,992	562,090
Percentage	.....	.....	26.0	16.4	34.5	76.9

System.	Unspecified items (10 per cent).	Overhead (20 per cent).	Total gross cost.	Credit for released steam locomotives.	Net cost.
Boston & Maine	2,872	5,745	37,342	8,480	28,862
Boston & Albany	1,743	3,486	22,658	4,420	18,238
New York, New Haven & Hartford	3,580	7,161	46,544	10,152	36,392
Delaware & Hudson	3,071	6,142	39,925	9,320	30,605
Erie	5,173	10,346	67,249	13,980	53,269
Delaware, Lackawanna & Western	4,934	9,868	64,141	13,360	50,781
Lehigh Valley	4,710	9,419	61,225	15,340	45,885
Central of New Jersey	3,371	6,741	43,818	11,820	31,998
Pennsylvania	15,604	31,208	202,850	42,560	160,290
Philadelphia & Reading	8,370	16,740	108,809	23,540	85,269
Baltimore & Ohio	2,781	5,563	36,157	7,660	28,497
	56,209	112,419	730,718	160,632	570,086
Percentage	7.7	15.4	100.0	22.0	78.0

TABLE 42.—*Comparative cost of steam and electric operation on selected divisions, in thousands of dollars.*

System.	Net cost of electric construction and equipment.	Cost of steam operation.		Cost of electric operation.			Saving by electric operation.		
		Coal.	Locomotive maintenance.	Energy.	Locomotive maintenance.	Distribution and substations.	Wage saving.	Total.	Ratio to cost of construction (per cent).
Boston & Maine	28,862	3,780	3,170	2,240	721	578	1,020	4,431	15.4
Boston & Albany	18,238	2,190	1,601	1,290	426	402	399	2,072	11.4
New York, New Haven & Hartford	36,392	4,949	4,737	2,971	849	838	991	6,019	16.5
Delaware & Hudson	30,605	4,208	2,984	2,757	677	727	795	3,826	12.5
Erie	53,269	5,467	6,913	3,398	936	1,216	1,032	7,862	14.8
Delaware, Lackawanna & Western	50,781	7,000	5,004	4,330	1,086	1,194	1,260	6,654	13.1
Lehigh Valley	45,885	5,514	5,170	3,668	869	1,041	1,205	6,311	13.8
Central of New Jersey	31,998	4,300	3,800	2,890	735	824	1,060	4,711	14.7
Pennsylvania	160,290	17,162	19,797	12,330	4,125	3,547	4,628	21,585	13.5
Philadelphia & Reading	85,269	10,998	8,976	6,353	1,819	2,099	2,574	12,277	14.4
Baltimore & Ohio	28,497	3,202	4,386	2,006	667	635	853	5,133	18.0
	570,086	68,770	66,538	44,233	12,910	13,101	15,817	80,881	14.2

Table 43 gives the comparative data for steam and electric operation, in accordance with Form C, for all the selected divisions within the zone, aggregated into one operating system. This table summarizes briefly the entire results of the investigation; it does not include wage saving.

TABLE 43.—*Comparison of steam and electric operation for all selected divisions (combined).*

	Freight.		Passenger.		Switcher.		All services.	
	Unit value.	Total.	Unit value.	Total.	Unit value.	Total.	Unit value.	Total.
Miles of road operated	.....	6,395	.....	6,395	.....	.....	.....	6,395
Miles of track	.....	11,296	.....	11,296	.....	7,831	.....	19,127
Steam.								
Average number of assigned locomotives	.....	2,927	.....	1,620	.....	1,995	.....	6,542
Weight on drivers. tons	97	283,171	65	104,655	74	147,058	82	534,884
Locomotive-miles, thousands	.....	58,517	.....	54,946	.....	42,882	.....	156,345
Trailing ton-miles, millions	.....	723,896	.....	.....	.....	.....	.....	.....
Car-miles...thousands	.....	.....	.....	.....	.....	.....	.....	.....
Coal burned.....tons	.....	7,424,500	.....	3,450,400	.....	2,438,600	.....	13,313,500
Coal per locomotive-mile.....pounds	.....	254	.....	126	.....	114	.....	170
Electric.								
Kilowatt-hours (thousand-ton-mile basis) .....thousands	36.8	2,666,400	.....	.....	.....	.....	.....	.....
Kilowatt-hours (locomotive-mile basis) .....thousands	45.6	2,666,400	20.6	1,133,000	14.6	623,900	28.3	4,423,300
Equivalent coal, pounds and tons	2.0	2,666,400	2.0	1,133,000	2.0	623,900	2.0	4,423,300
Coal saved, per cent and tons	64.1	4,758,100	67.2	2,317,400	74.4	1,814,700	66.8	8,890,200
Unit and total cost.								
Cost of coal and water	$5.17	$38,350,800	.....	$17,822,800	.....	$12,596,600	$5.17	$68,770,200
Cost of electric energy	.01	26,664,000	.....	11,330,000	.....	6,239,000	.....	44,233,000
Excess cost of steam	.....	11,686,800	.....	6,492,800	.....	6,357,600	.....	24,537,200
Locomotive maintenance, steam[a]	.49	28,649,500	$0.396	21,766,900	$0.376	16,121,200	.426	66,537,600
Locomotive maintenance, electric[a]	.0826	4,831,800	.....	4,537,000	.....	3,540,800	.0826	12,909,600
Maintenance of distribution system	600.00	3,545,800	.....	3,325,900	400.00	3,132,400	.....	10,004,100
Substation operation and maintenance	.0007	1,866,600	.....	793,100	.....	436,800	.0007	3,096,500
Total cost, steam operation	.....	67,000,300	.....	39,589,700	.....	28,717,800	.....	135,307,800
Total cost, electric operation	.....	36,908,200	.....	19,986,000	.....	13,349,000	.....	70,243,200
Excess cost, steam operation	2,664.00	30,092,100	1,735.00	19,603,700	1,963.00	15,368,800	3,402.00	65,064,600

[a] Includes engine-house expense.

Figure 16 shows the growth of traffic, both freight and passenger, of track, and of tractive power for the class 1 railroads in the superpower zone from 1900 to 1919. The annual rate of growth has been 5.3 per cent in passenger-miles, 4.5 per cent in ton-miles, 0.75 per cent in all track, and 6.6 per cent in tractive power of locomotives.

The amount of money required for electrification is indicated in Table 42 as $570,000,000. This figure is based on costs prevailing in 1919, but at present costs (June, 1921) it would be reduced by 18 per cent, to approximately $467,000,000, and before this construction can be undertaken there will be further material reductions. Probably five years from now the entire work outlined could be done for not more than $400,000,000. This is comparatively a moderate sum. Good railroad authorities have stated repeatedly that more than $1,000,000,000 a year is needed by the railroads of the United States for extensions and betterments. The part of this total to be allocated to the superpower zone, as determined by the number of locomotives,

would be $150,000,000. The amount required for normal extensions and betterments for three years would therefore be sufficient to electrify the 30 selected divisions of the railroads in this territory, with an annual saving of more than 14 per cent. The most valuable feature of the change, however, is not the amount saved but the great increase in maximum capacity of existing trackage and the general advantages of electric operation.

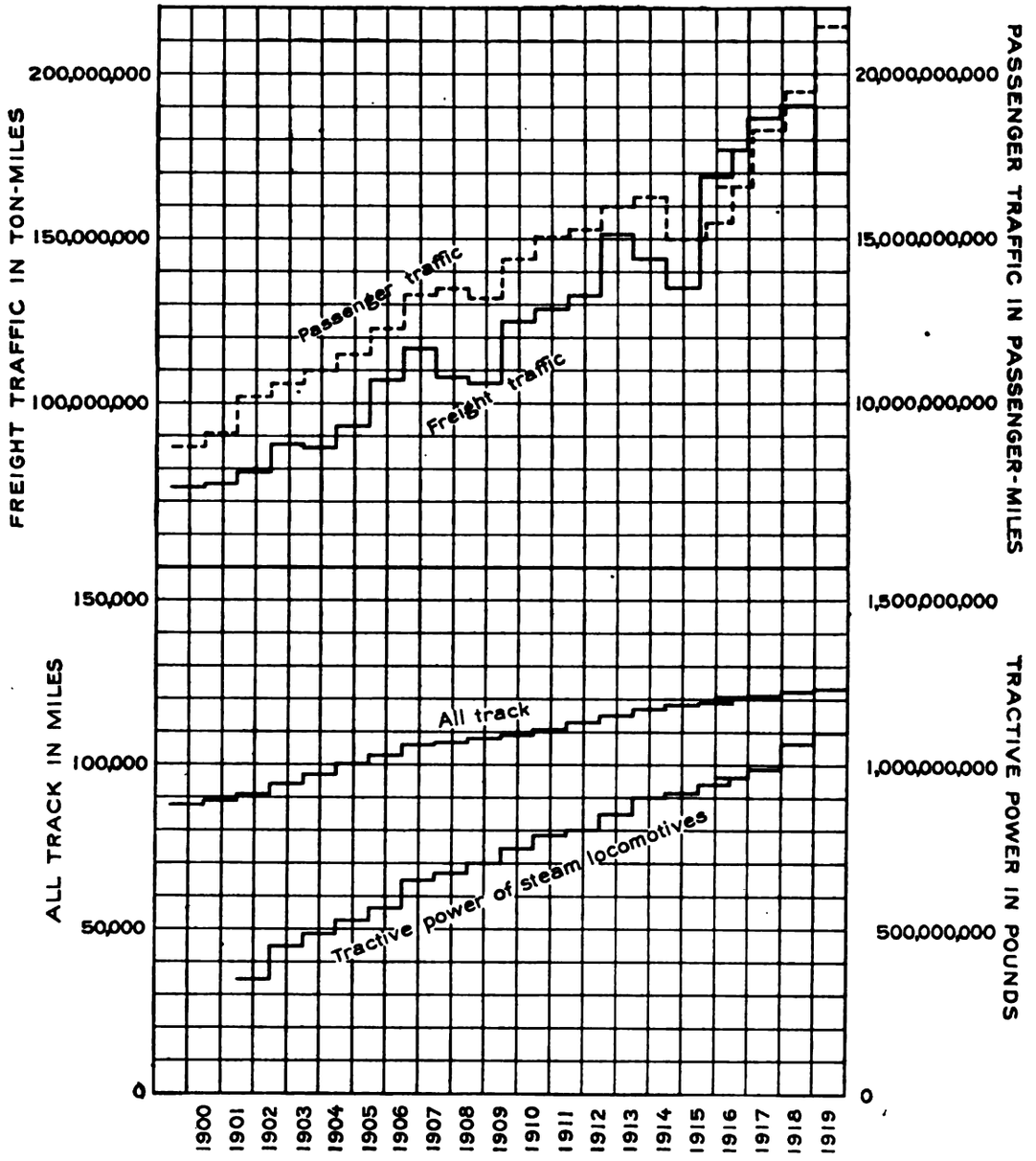


FIGURE 16.—Growth of steam railroads in the superpower zone in 1900–1919. Annual rate of growth compounded, 1900–1918: Passenger-miles, 5.3 per cent; ton-miles, 4.5 per cent; all track, 0.75 per cent; tractive power, 6.6 per cent.

These figures indicate that with a return of normal financial conditions all these lines should be electrified before further great expenditures have been incurred to increase in a minor degree the capacity of the existing tracks and yards. Steam operation can not satisfactorily meet the conditions of the crowded terminal herein described as the superpower zone; electric operation can easily do it.

APPENDIX D.

INDUSTRY IN THE SUPERPOWER ZONE.

By H. W. Butler, H. Goodwin, Jr., and others of the engineering staff.

CONCLUSIONS.

A survey of the industrial establishments in the superpower zone in 1919 shows that the maximum economical use of purchased power in that year would have saved 13,502,100 tons of coal. This estimate assumes a consumption equivalent to 2 pounds of coal per kilowatt-hour at the motor leads in the industrial establishments. In order to save this coal, however, the industries would have had to purchase 5,623,800,000 kilowatt-hours more than they did.

The energy developed by prime movers in the industries was equivalent to 9,311,440,000 kilowatt-hours. The energy purchased from central electric stations to supply electric motors in the industries was 3,338,800,000 kilowatt-hours.

INDUSTRIES CONSIDERED.

"Industries" as used in this report means privately owned manufacturing establishments, laundries, mines and quarries, and Government institutions. The establishments considered include only those whose annual product has a value greater than $500. Table 48 gives the statistics for 53 industries, which have been arranged in 17 major groups adopted by the Bureau of the Census, to permit convenient comparison of the information here given with other information gathered by the Census Bureau regarding these industries.

FUNDAMENTAL INFORMATION RECEIVED FROM BUREAU OF THE CENSUS.

THE TABLES IN GENERAL.

The only source of general figures showing power and fuel used proved to be the Bureau of the Census. The census of manufactures covering the calendar year 1919 was in process of compilation, and the Census Bureau arranged to cooperate with the superpower survey by supplying advance information in special tabular form for analysis. The titles of the tables follow:

Table 44.—Mechanical power-supply equipment and fuel used by all industries, by size of plant.

Table 45.—Mechanical power-supply equipment and fuel used by all industries, by character of power supply.

Table 46.—Mechanical power-supply equipment and fuel used by all industries, by industry subgroups and character of power supply.

Table 47.—Mechanical power-supply equipment and fuel used by all industries, by counties and size of plant.

Table 48.—Summary and analysis of industrial power and fuel, by industry groups. (The summary consists of Census data; the analysis was made by the superpower survey.)

The column headings are practically the same in all tables. They follow the Census standard headings except as noted.

"Power-supply equipment" is used instead of the old Census term "primary power."

"Prime movers" is used instead of "owned" power.

"Operated by purchased energy" is used instead of "rented" power.

"Aggregate horsepower" of "power-supply equipment" (column 6) is the sum of the "total horsepower" of "prime movers" (column 7) and the "total horsepower" "operated by purchased energy" (column 16).

"Total horsepower" of "prime movers" (column 7) is the sum of columns 9, 11, 13, and 15. Prime movers are included whether they are directly connected to machinery, such as pumps, air compressors, or electrical generators, or used to drive shafting. Boiler-room and engine-room auxiliaries are not included.

"Internal-combustion engines" (columns 12 and 13) include gas, gasoline, and oil engines, whether run on special fuel or waste gases.

"Water wheels" (columns 14 and 15) include hydraulic turbines and an insignificant number of small water motors run from city water mains.

"Electric motors" "operated by purchased energy" (columns 17 and 18) consist chiefly of motors operated from the circuits of central stations but include also some that are operated by energy purchased from isolated plants.

"Other horsepower" "operated by purchased energy" (column 19) is chiefly power received through belting or shafting from the power plant of some other industrial establishment.

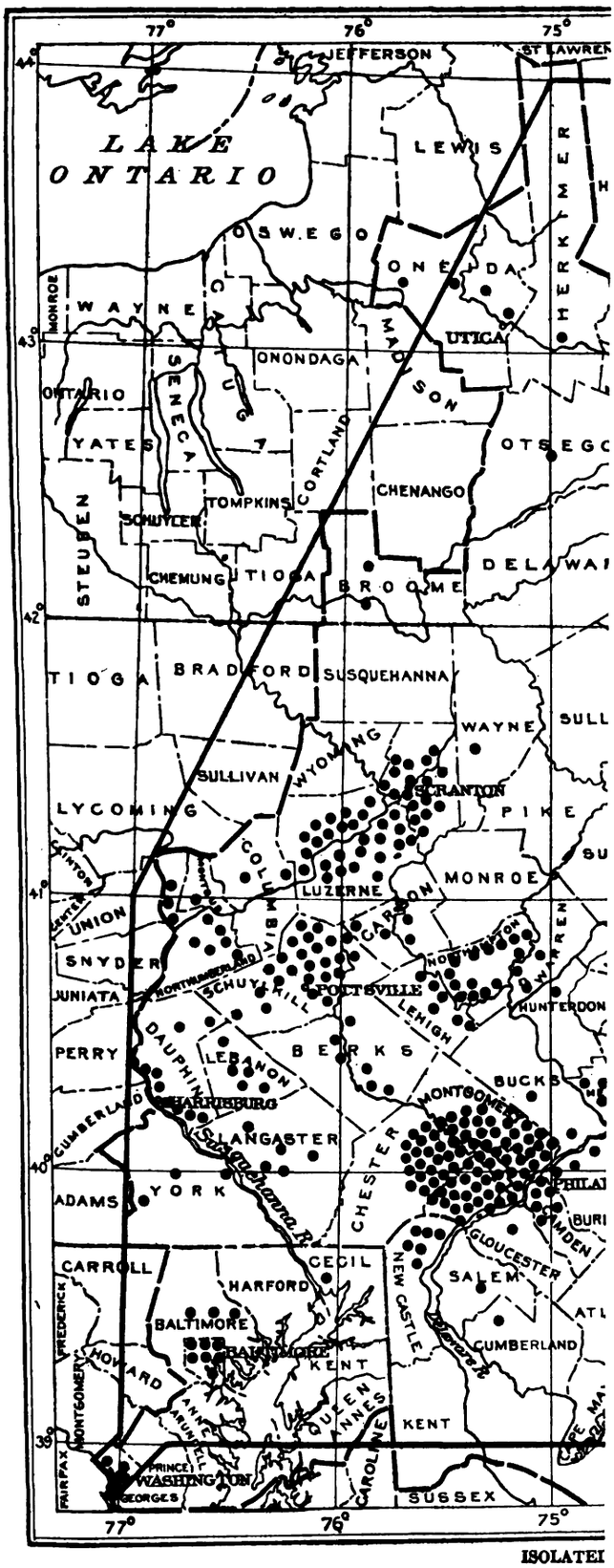
"Total number" of "electric motors" (column 20) is the sum of those "operated by purchased energy" (column 17) and those "run by current generated in establishment" (column 22). Similarly "Total horsepower" (column 21) is the sum of columns 18 and 23. A comparison of column 21 with column 6 gives an idea of the application of electricity in any industry.

"Fuel used" is expressed in "long tons" (2,240 pounds) for anthracite and "short tons" (2,000 pounds) for bituminous coal and coke. Column 26 ("Total equivalent bituminous coal") is derived from columns 24 and 25 and is presented to permit a comparison of items that show various proportions of anthracite and bituminous coal. A careful investigation of the quality of coal used by the industries showed that one long ton of anthracite was equivalent, on the average, to about nine-tenths of a short ton of bituminous coal in producing power. The "total equivalent bituminous coal" is therefore determined by multiplying the "anthracite" tons by 0.9 and adding the result to the "bituminous" tons. As comparatively little coke is used for producing power in the superpower zone, this item is not included in the "total equivalent bituminous coal."

Statistics on the use of oil and manufactured gas in the industries are also compiled by the Bureau of the Census, but the data for 1919 were not ready in time for use. The amount of oil used for producing power is very small in comparison with the amount of coal used, and as the oil reserves are scant it must remain small.

LIMITATIONS OF STATISTICS.

It is difficult to show the present complicated conditions in industry, with its interrelated power and fuel supply, in a few uniform tables. The totals given are undoubtedly very accurate, but as the divisions become finer and finer they must be used with increasing care and knowledge of the rules used in compilation. For instance: (*a*) Many plants, particularly the larger ones, that are normally operated by water power have complete steam plants in reserve for their operation during periods of low water. Both forms of power are reported, and in a small group either may apparently show a disproportionately large amount of power. (*b*) Some plants have discontinued regular operation of direct prime movers and purchase power from a central station but must also report the old prime movers held in reserve. This again leads to a duplication. (*c*) Other plants are electrically driven throughout and purchase power part of the time and generate it another part. At some times the central station connection is only "reserve," and at other times the prime movers are only "reserve," so that to avoid duplication and to make the total as nearly correct as possible, it is necessary to report the motors as "run by current generated in establishment reporting." If the prime movers are used only occasionally, the report obviously does not give the central station any credit for what it supplies. (*d*) Still other plants abandoned the use of prime movers near the end of 1919 and purchased all energy. Thus the statistics show that the motors were operated by purchased energy on December 31, 1919, but that the fuel used during the year was almost enough to operate a steam plant instead of the small amount that might be needed with purchased power. This condition happened to be particularly true of ice plants, many of which changed to central-station service in 1919.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MADISON
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SENECA
YATES
CORTLAND
OTSEGO
CHENANGO
TOMPKINS
SCHUYLER
STEUBEN
CHEMUNG
TIOGA
BROOME
DELAWA
TIOGA
BRADFORD
SUSQUEHANNA
WAYNE
SULL
WYOMING
SULLIVAN
SCRANTON
LYCOMING
PIKE
COLUMBIA
LUZERNE
MONROE
UNION
CARBON
SNYDER
NORTHUMBERLAND
SCHUYLKILL
POTTSVILLE
NORTHAMPTON
WARREN
JUNIATA
LEHIGH
HUNTERDON
PERRY
DAUPHIN
LEBANON
BERKS
BUCKS
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FREDERICK
HOWARD
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QUEEN ANNES
KENT
CAROLINE
PRINCE GEORGES
WASHINGTON
FAIRFAX
SUSSEX

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THE TABLES IN DETAIL.

Table 44 shows the total mechanical power-supply equipment and fuel used by all industries in the zone, by size of plant. First is shown the fuel used by establishments reporting "no power." On the following lines are given the power and fuel used by establishments reporting an aggregate of 1 to 200 horsepower, 201 to 500 horsepower, and 501 horsepower or more. The average size is interesting. The figures for the larger plants indicate that 2,732 establishments use 6,689,751 horsepower—that is, 3.6 per cent of the establishments reporting power are larger than 500 horsepower and use 73.8 per cent of the grand total horsepower.

Table 45 shows the total mechanical power-supply equipment and fuel, by character of power supply, with each group subdivided by size of plant. This subdivision is made particularly for analysis. Therefore two clear-cut groups have been selected—establishments reporting "steam power only" and establishments reporting "purchased electric power only." The ratio of fuel used to power is in these establishments obviously simple, and the amount of coal used per horsepower has a definite significance. All combinations of steam power with purchased power and all other forms of power exhibit more complicated relations and have been thrown together under the heading "All other power." The relations in this group may usually be analyzed by means of the factors derived from the previous groups by making proper allowance for the considerations noted above under "Limitations of statistics."

Table 46 presents data for each industrial subgroup similar to those presented for all industries in Table 45. The totals of each group in Table 46 are carried forward to Table 48. Remarks in regard to Table 45 apply to Table 46 with additional force. This table shows clearly for each group of industries the character of power supply and the fuel used, from which can be determined the relation of fuel used to character of power supply.

Table 47 gives the mechanical power-supply equipment reported in each county, by size of plant, as explained for Table 44. This table is of interest as showing the distribution of plants of various sizes and the extent to which electric power is purchased in different counties.

Plate VII shows the distribution by counties of isolated-plant power, each dot representing 10,000 horsepower of steam, oil, or gasoline engines.

TABLE 44.—*Mechanical power-supply equipment and*

[Data from census of

Industry subgroup.	Character of power supply.	Size of plant (horsepower).	Establishments.		Power-supply equipment.									
						Prime movers.								
			Number.	Average size (horsepower).	Aggregate horsepower.	Total horsepower.	Steam engines.		Steam turbines.		Internal-combustion engines.		Water wheels.	
							Number.	Horsepower.	Number.	Horsepower.	Number.	Horsepower.	Number.	Horsepower.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Grand total, all industries.	No power		19,757	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	All power:													
		1-200	70,654	21	1,485,664	692,047	11,022	535,505	276	10,135	5,511	73,408	2,333	72,999
		201-500	2,841	315	894,056	569,154	4,618	488,880	174	19,514	294	11,662	627	49,098
		501 and above	2,732	2,450	6,689,751	4,985,801	17,739	3,231,483	1,665	1,141,412	441	193,970	1,748	418,936
	Total power		76,227	119	9,069,471	6,247,002	33,379	4,255,868	2,115	1,171,061	6,246	279,040	4,708	541,033
	Grand total		95,984	.....	9,069,471	6,247,002	33,379	4,255,868	2,115	1,171,061	6,246	279,040	4,708	541,033

TABLE 45.—*Mechanical power-supply equipment and*

[Data from census of

Industry subgroup.	Character of power supply.	Size of plant (horsepower).	Establishments.		Power-supply equipment.									
						Prime movers.								
			Number.	Average size (horsepower).	Aggregate horsepower.	Total horsepower.	Steam engines.		Steam turbines.		Internal-combustion engines.		Water wheels.	
							Number.	Horsepower.	Number.	Horsepower.	Number.	Horsepower.	Number.	Horsepower.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Grand total, all industries.	No power		19,757	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	Steam power only:													
		1-200	6,446	61	395,029	395,029	7,886	388,054	174	6,975	.....	.....	.....	.....
		201-500	949	322	305,909	305,909	2,380	291,745	118	14,164	.....	.....	.....	.....
		501 and above	912	2,210	2,017,858	2,017,858	7,357	1,437,942	790	579,916	.....	.....	.....	.....
			8,307	327	2,718,796	2,718,796	17,623	2,117,741	1,082	601,055	.....	.....	.....	.....
	Purchased electric power only:													
		1-200	53,968	13	680,456	.....	.....	.....	.....	.....	.....	.....	.....	.....
		201-500	681	303	206,611	.....	.....	.....	.....	.....	.....	.....	.....	.....
		501 and above	367	1,620	596,240	.....	.....	.....	.....	.....	.....	.....	.....	.....
			55,016	27	1,483,307	.....	.....	.....	.....	.....	.....	.....	.....	.....
	All other power:													
		1-200	10,240	40	410,179	297,018	3,136	147,451	102	3,160	5,511	73,408	2,333	72,999
		201-500	1,211	314	381,536	263,245	2,238	197,135	56	5,350	294	11,662	627	49,098
		501 and above	1,453	2,800	4,075,653	2,967,943	10,382	1,793,541	875	561,496	441	193,970	1,748	418,936
			12,904	377	4,867,368	3,528,206	15,756	2,138,127	1,033	570,006	6,246	279,040	4,708	541,033
	Total power		76,227	119	9,069,471	6,247,002	33,379	4,255,868	2,115	1,171,061	6,246	279,040	4,708	541,033
	Grand total		95,984	.....	9,069,471	6,247,002	33,379	4,255,868	2,115	1,171,061	6,246	279,040	4,708	541,033

fuel used by all industries, by size of plant.

manufactures, 1919.]

Power-supply equipment—Continued.				Electric motors.				Fuel used.			
Operated by purchased energy.											
Total horsepower.	Electric motors.		Other (horsepower).	Total.		Run by current generated in establishment.		Coal.			Coke (short tons).
	Number.	Horsepower.		Number.	Horsepower.	Number.	Horsepower.	Anthracite (long tons).	Bituminous (short tons).	Total equivalent bituminous (short tons).	
16	17	18	19	20	21	22	23	24	25	26	27
.....	.....	.....	.....	.....	.....	.....	.....	234,010	381,727	591,884	25,860
793,617	208,962	763,163	30,454	221,738	837,261	12,776	74,098	2,528,361	3,887,872	6,158,375	566,778
334,902	35,593	321,592	3,310	58,228	481,523	22,635	159,931	1,265,149	3,899,249	5,037,683	308,288
1,703,950	117,406	1,685,960	17,990	280,941	4,017,843	163,535	2,331,883	16,882,346	26,496,476	41,675,571	4,760,102
2,822,469	361,961	2,770,715	51,754	560,907	5,336,627	198,946	2,565,912	20,675,855	34,287,597	52,871,629	5,635,168
2,822,469	361,961	2,770,715	51,754	560,907	5,336,627	198,946	2,565,912	20,909,865	34,669,324	53,463,513	5,661,028

fuel used by all industries, by character of power supply.

manufactures, 1919.]

Power-supply equipment—Continued.				Electric motors.				Fuel used.			
Operated by purchased energy.											
Total horsepower.	Electric motors.		Other (horsepower).	Total.		Run by current generated in establishment.		Coal.			Coke (short tons).
	Number.	Horsepower.		Number.	Horsepower.	Number.	Horsepower.	Anthracite (long tons).	Bituminous (short tons).	Total equivalent bituminous (short tons).	
16	17	18	19	20	21	22	23	24	25	26	27
.....	.....	.....	.....	.....	.....	.....	.....	234,010	381,727	591,884	25,860
.....	.....	.....	.....	8,633	52,326	8,633	52,326	855,337	1,886,507	2,655,485	149,745
.....	.....	.....	.....	17,179	115,860	17,179	115,860	657,603	1,889,242	2,480,059	131,501
.....	.....	.....	.....	88,382	1,143,666	88,382	1,143,666	7,070,078	12,139,926	18,500,448	2,286,003
.....	.....	.....	.....	114,194	1,311,852	114,194	1,311,852	8,583,018	15,915,675	23,635,992	2,567,249
680,456	196,275	680,456	.....	196,275	680,456	.....	.....	1,091,594	965,127	1,943,805	338,435
206,611	23,709	206,611	.....	23,709	206,611	.....	.....	123,109	575,813	685,748	44,734
596,240	38,790	596,240	.....	38,790	596,240	.....	.....	197,520	2,542,126	2,719,861	100,182
1,483,307	258,774	1,483,307	.....	258,774	1,483,307	.....	.....	1,412,223	4,083,066	5,349,414	483,351
113,161	12,687	82,707	30,454	16,830	104,479	4,143	21,772	581,430	1,036,238	1,559,085	78,598
118,201	11,384	114,961	3,310	17,340	159,052	5,456	44,071	484,437	1,436,194	1,871,876	132,053
1,107,710	78,616	1,089,720	17,990	153,769	2,277,937	75,153	1,188,217	9,614,748	11,816,424	20,455,262	2,373,917
1,339,162	103,187	1,287,408	51,754	187,939	2,541,468	84,752	1,254,060	10,680,615	14,288,856	23,886,223	2,584,568
2,822,469	361,961	2,770,715	51,754	560,907	5,336,627	198,946	2,565,912	20,675,855	34,287,597	52,871,629	5,635,168
2,822,469	361,961	2,770,715	51,754	560,907	5,336,627	198,946	2,565,912	20,909,865	34,669,324	53,463,513	5,661,028

TABLE 46.—*Mechanical power-supply equipment and fuel*

[Data from census of

Industry subgroup.	Character of power supply.	Size of plant (horsepower).	Establishments.		Power-supply equipment.									
						Prime movers								
			Number.	Average size (horsepower).	Aggregate horsepower.	Total horsepower.	Steam engines.		Steam turbines.		Internal-combustion engines.		Water wheels.	
							Number.	Horsepower.	Number.	Horsepower.	Number.	Horsepower.	Number.	Horsepower.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1a. Slaughtering.	No power		171											
	Steam power only:													
		1-200	68	48	3,191	3,191	92	3,129	3	62				
		201-500	14	330	4,682	4,682	52	4,682	0	0				
		501 and above	14	1,020	14,270	14,270	72	13,173	9	1,097				
			96	230	22,143	22,143	216	20,984	12	1,159				
	Purchased electric power only:													
		1-200	343	21	7,228									
		201-500	5	281	1,406									
			348	25	8,634									
	All other power:													
		1-200	87	32	2,755	1,626	53	1,546	3	80	0	0	0	0
		201-500	14	295	4,114	2,158	32	2,013	2	145	0	0	0	0
		501 and above	7	1,808	12,654	7,423	31	5,830	8	1,593	0	0	0	0
			108	1,800	19,523	11,207	116	9,389	13	1,818	0	0	0	0
	Total power		552	91	50,300	33,350	332	30,373	25	2,977	0	0	0	0
	Grand total		723		50,300	33,350	332	30,373	25	2,977	0	0	0	0
1b. Flour-mill and grist-mill products.	No power		4											
	Steam power only:													
		1-200	111	5	6,430	6,430	108	6,315	3	115				
		201-500	1	225	225	225	1	225	0	0				
		501 and above	2	700	1,400	1,400	5	1,400	0	0				
			114	70	8,055	8,055	114	7,940	3	115				
	Purchased electric power only:													
		1-200	245	38	9,431									
		201-500	2	362	725									
			247	41	10,156									
	All other power:													
		1-200	847	43	36 351	34,498	57	2,865	1	50	239	5,431	1,017	26,152
		201-500	7	310	2,173	1,705	1	150	0	0	1	40	14	1,515
		501 and above	2	690	1,380	1,330	3	650	0	0	0	0	14	680
			856	47	39,904	37,533	61	3,665	1	50	240	5,471	1,045	28,347
	Total power		1,217	48	58,115	45,588	175	11,605	4	165	240	5,471	1,045	23,347
	Grand total		1,221		58,115	45,588	175	11,605	4	165	240	5,471	1,045	23,347
1c. Bread and bakery products.	No power		2,949											
	Steam power only:													
		1-200	22	51	1,118	1,118	24	1,043	1	75				
		201-500	11	362	3,987	3,987	29	3,987	0	0				
		501 and above	6	1,473	8,839	8,839	28	6,839	6	2,000				
			39	356	13,944	13,944	81	11,869	7	2,075				
	Purchased electric power only:													
		1-200	5,357	6	30,693									
		201-500	9	264	2,375									
		501 and above	2	940	1,881									
			5,368	6	34,949									
	All other power:													
		1-200	182	23	4,190	2,535	40	1,507	3	11	139	995	8	22
		201-500	6	264	1,582	1,047	14	1,047	0	0	0	0	0	0
		501 and above	3	2,570	7,712	1,030	5	630	1	400	0	0	0	0
			191	70	13,484	4,612	59	3,184	4	411	139	995	8	22
	Total power		5,598	11	62,377	18,556	140	15,053	11	2,486	139	995	8	22
	Grand total		8,547		62,377	18,556	140	15,053	11	2,486	139	995	8	22

used by industry subgroups, by character of power supply.

manufactures, 1919.]

Power-supply equipment—Continued.				Electric motors.				Fuel used.			
Operated by purchased energy.				Total.		Run by current generated in establishment.		Coal.			Coke (short tons).
Total horsepower.	Electric motors.		Other (horsepower).					Anthracite (long tons).	Bituminous (short tons).	Total equivalent bituminous (short tons).	
	Number.	Horsepower.		Number.	Horsepower.	Number.	Horsepower.				
16	17	18	19	20	21	22	23	24	25	26	27
.....	.....	.....	.....	.....	.....	.....	.....	467	548	978	0
.....	.....	.....	.....	81	703	81	703	14,496	16,339	29,389	47
.....	.....	.....	.....	202	2,284	202	2,284	15,131	35,365	51,965	0
.....	.....	.....	.....	574	6,608	574	6,608	81,593	97,844	171,344	7,358
.....	.....	.....	.....	857	9,595	857	9,595	111,220	152,548	252,698	7,405
7,228	865	7,228	.....	865	7,228	.....	.....	4,372	7,380	11,310	126
1,406	96	1,406	.....	96	1,406	.....	.....	96	2,398	2,485	0
8,634	961	8,634	.....	961	8,634	.....	.....	4,468	9,778	13,795	126
1,129	93	987	142	98	1,001	5	14	5,333	12,375	17,175	106
1,956	187	1,956	0	227	2,303	40	347	14,049	14,656	27,256	.....
5,231	447	5,231	0	561	6,517	114	1,286	89,131	26,949	106,949	.....
8,316	727	8,174	142	886	9,821	159	1,647	108,513	53,980	151,380	106
16,950	1,688	16,808	142	2,704	23,050	1,016	11,242	224,201	216,306	417,873	7,637
16,950	1,688	16,808	142	2,704	23,050	1,016	11,242	224,668	216,854	418,851	7,637
.....	.....	.....	.....	.....	.....	.....	.....	0	0	0	0
.....	.....	.....	.....	2	11	2	11	8,896	10,155	18,145	0
.....	.....	.....	.....	0	0	0	0	0	1,050	1,050	0
.....	.....	.....	.....	13	128	13	128	7,500	4,080	10,830	0
.....	.....	.....	.....	15	139	15	139	16,396	15,285	30,025	0
9,431	710	9,431	.....	710	9,431	.....	.....	670	602	1,205	4
725	31	725	.....	31	725	.....	.....	0	0	0	0
10,156	741	10,156	.....	741	10,156	.....	.....	670	602	1,205	4
1,853	107	1,775	78	123	1,996	16	221	7,968	3,993	11,173	80
468	40	468	0	79	968	39	500	49	870	914	0
50	1	50	0	1	50	0	0	0	362	363	0
2,371	148	2,293	78	203	3,014	55	721	8,037	5,225	12,450	80
12,527	889	12,449	78	959	13,309	70	860	25,103	21,112	43,680	81
12,527	889	12,449	78	959	13,309	70	860	25,103	21,112	43,680	81
.....	.....	.....	.....	.....	.....	.....	.....	90,662	8,137	89,637	16,511
.....	.....	.....	.....	50	355	50	355	2,335	13,040	15,140	0
.....	.....	.....	.....	353	2,560	353	2,560	18,634	14,540	31,340	3,775
.....	.....	.....	.....	1,035	5,812	1,035	5,812	43,280	13,268	52,268	938
.....	.....	.....	.....	1,438	8,727	1,438	8,727	64,249	40,848	98,748	4,743
30,693	10,296	30,693	.....	10,296	30,693	.....	.....	261,464	38,469	273,469	50,984
2,375	425	2,375	.....	425	2,375	.....	.....	8,086	2,077	9,337	1,168
1,881	317	1,881	.....	317	1,881	.....	.....	5,715	473	5,623	0
34,949	11,038	34,949	.....	11,038	34,949	.....	.....	275,265	41,019	288,429	52,152
1,655	346	1,638	17	457	2,113	111	475	17,028	10,580	25,880	1,699
535	74	535	0	124	844	50	309	12,082	5,205	16,105	0
6,682	277	6,682	0	414	7,329	137	647	13,565	8,320	20,520	1,858
8,872	697	8,855	17	995	10,286	298	1,431	42,675	24,105	62,505	3,557
43,821	11,735	43,804	17	13,471	53,962	1,736	10,158	382,189	105,972	449,682	60,452
43,821	11,735	43,804	17	13,471	53,962	1,736	10,158	472,851	114,109	539,319	76,963

TABLE 46.—*Mechanical power-supply equipment and fuel used*

Industry subgroup.	Character of power supply.	Size of plant (horsepower).	Establishments.		Power-supply equipment.									
						Prime movers.								
							Steam engines.		Steam turbines.		Internal-combustion engines.		Water wheels.	
			Number.	Average size (horsepower).	Aggregate horsepower.	Total horsepower.	Number.	Horsepower.	Number.	Horsepower.	Number.	Horsepower.	Number.	Horsepower.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1d. Sugar refining.	Steam power only:	501 and above	13	2,700	35,041	35,041	229	23,678	22	11,363				
		Total power	13	2,700	35,041	35,041	229	23,678	22	11,363				
1e. All other food products.	No power		806											
	Steam power only:	1-200	687	32	21,836	21,836	854	21,611	19	225				
		201-500	31	328	10,211	10,211	93	10,101	3	110				
		501 and above	15	906	13,638	13,638	73	12,828	4	810				
			733	62	45,685	45,685	1,020	44,540	26	1,145				
	Purchased electric power only:	1-200	2,474	15	36,219									
		201-500	40	299	11,947									
		501 and above	7	804	5,631									
			2,521	21	53,797									
	All other power:	1-200	765	30	23,305	17,412	275	9,552	10	276	602	6,108	66	1,476
		201-500	36	300	10,831	6,281	84	5,135	3	226	17	670	1	250
		501 and above	30	1,524	45,733	30,171	110	26,306	11	990	31	2,548	15	327
			831	96	79,869	53,864	469	40,993	24	1,492	640	9,326	82	2,053
	Total power		4,085	44	179,351	99,549	1,489	85,533	50	2,637	640	9,326	82	2,053
	Grand total		4,891		179,351	99,549	1,489	85,533	50	2,637	640	9,326	82	2,053
2a. Cotton goods, small wares, and lace.	No power		13											
	Steam power only:	1-200	48	123	5,937	5,937	61	5,937	0	0				
		201-500	22	345	7,593	7,593	38	7,493	1	100				
		501 and above	72	2,395	172,596	172,596	162	145,539	28	27,057				
			142	1,310	186,126	186,126	261	158,969	29	27,157				
	Purchased electric power only:	1-200	193	51	9,839									
		201-500	14	320	4,506									
		501 and above	19	2,760	52,579									
			226	295	66,924									
	All other power:	1-200	95	57	5,436	3,630	23	1,411	0	0	22	509	31	1,710
		201-500	30	347	10,425	9,386	36	5,405	0	0	0	0	39	3,981
		501 and above	183	3,420	626,602	514,737	452	252,998	92	124,393	10	1,465	592	135,881
			308	2,080	642,463	527,753	511	259,814	92	124,393	32	1,974	662	141,572
	Total power		676	1,320	895,513	713,879	772	418,783	121	151,550	32	1,974	662	141,572
	Grand total		689		895,513	713,879	772	418,783	121	151,550	32	1,974	662	141,573
2b. Knit goods.	No power		61											
	Steam power only:	1-200	129	74	9,552	9,552	140	9,301	5	251				
		201-500	12	308	3,696	3,696	18	3,696	0	0				
		501 and above	6	1,197	7,183	7,183	13	3,515	5	3,668				
			147	139	20,431	20,431	171	16,512	10	3,919				
	Purchased electric power only:	1-200	949	15	14,401									
		201-500	9	278	2,497									
		501 and above	4	1,071	4,285									
			962	22	21,183									
	All other power:	1-200	152	49	7,450	4,765	68	3,336	1	35	24	235	33	1,159
		201-500	40	310	12,394	8,535	40	6,275	2	110	0	0	30	2,150
		501 and above	21	1,330	27,981	19,671	52	13,672	2	1,750	0	0	28	4,249
			213	224	47,825	32,971	160	23,283	5	1,895	24	235	91	7,558
	Total power		1,322	68	89,439	53,402	331	39,795	15	5,814	24	235	91	7,558
	Grand total		1,383		89,439	53,402	331	39,795	15	5,814	24	235	91	7,558

by industry subgroups, by character of power supply—Continued.

Power-supply equipment—Continued.				Electric motors.				Fuel used.			
Operated by purchased energy.				Total.		Run by current generated in establishment.		Coal.			
Total horsepower.	Electric motors.		Other (horsepower).					Anthracite (long tons).	Bituminous (short tons).	Total equivalent bituminous (short tons).	Coke (short tons).
	Number.	Horsepower.		Number.	Horsepower.	Number.	Horsepower.				
16	17	18	19	20	21	22	23	24	25	26	27
.....	.....	.....	.....	2,582	37,090	2,582	37,090	406,248	865,118	1,231,118	180
.....	.....	.....	.....	2,582	37,090	2,582	37,090	406,248	865,118	1,231,118	180
.....	.....	.....	.....	.....	.....	.....	.....	4,330	12,777	16,674	431
.....	.....	.....	.....	493	2,558	493	2,558	40,226	104,951	141,158	281
.....	.....	.....	.....	562	3,371	562	3,371	14,988	42,175	55,675	991
.....	.....	.....	.....	1,547	11,893	1,547	11,893	67,331	22,864	83,461	420
.....	.....	.....	.....	2,602	17,822	2,602	17,822	122,545	169,990	280,294	1,692
3,6219	7,910	36,219	.....	7,910	36,219	.....	.....	43,464	50,252	89,365	1,739
11,947	1,420	11,947	.....	1,420	11,947	.....	.....	9,553	19,746	28,345	1,457
5,631	708	5,631	.....	708	5,631	.....	.....	1,914	4,957	6,679	0
53,797	10,038	53,797	.....	10,038	53,797	.....	.....	54,931	74,955	124,389	3,196
5,893	1,138	5,387	506	1,228	6,014	90	627	23,631	61,596	82,854	115
4,550	515	4,190	360	802	5,482	287	1,292	12,957	41,334	53,000	16
15,562	1,812	15,562	0	3,457	31,487	1,645	15,925	168,572	124,850	276,563	64
26,005	3,465	25,139	866	5,487	42,983	2,022	17,844	205,150	227,780	412,417	195
79,802	13,503	78,936	866	18,127	114,602	4,624	35,666	382,626	472,725	817,100	5,083
79,802	13,503	78,936	866	18,127	114,602	4,624	35,666	386,956	485,502	833,774	5,514
.....	.....	.....	.....	.....	.....	.....	.....	0	1,648	1,648	0
.....	.....	.....	.....	133	787	133	787	14,355	23,777	36,877	350
.....	.....	.....	.....	181	1,749	181	1,749	7,732	28,036	34,996	0
.....	.....	.....	.....	3,347	46,366	3,347	46,366	99,563	410,178	499,678	13,982
.....	.....	.....	.....	3,661	48,902	3,661	48,902	121,650	461,991	571,351	14,332
9,839	2,227	9,839	.....	2,227	9,839	.....	.....	3,901	12,108	15,608	399
4,506	865	4,506	.....	865	4,506	.....	.....	1,794	7,163	8,783	0
52,579	3,629	52,579	.....	3,629	52,579	.....	.....	4,891	14,501	18,901	0
66,924	6,721	66,924	.....	6,721	66,924	.....	.....	10,586	33,772	43,292	399
1,806	75	723	1,083	99	898	24	175	2,178	14,601	16,551	1
1,039	67	1,039	0	236	2,256	169	1,217	7,305	33,930	40,501	0
111,865	10,250	111,470	395	20,259	267,788	10,009	156,318	166,061	1,137,722	1,278,722	1,694
114,710	10,392	113,232	1,478	20,594	270,942	10,202	157,710	175,544	1,186,253	1,335,774	1,695
181,634	17,113	180,156	1,478	30,976	386,768	13,863	206,612	307,780	1,682,016	1,950,417	16,426
181,634	17,113	180,156	1,478	30,976	386,768	13,863	206,612	307,780	1,683,664	1,952,065	16,426
.....	.....	.....	.....	.....	.....	.....	.....	193	201	374	0
.....	.....	.....	.....	642	2,937	642	2,937	22,773	42,714	63,114	43
.....	.....	.....	.....	555	1,576	555	1,576	10,163	10,446	19,546	0
.....	.....	.....	.....	814	4,747	814	4,747	17,694	20,390	36,290	74
.....	.....	.....	.....	2,011	9,260	2,011	9,260	50,630	73,550	118,950	117
14,401	3,885	14,401	.....	3,885	14,401	.....	.....	16,698	40,666	55,666	41
2,497	526	2,497	.....	526	2,497	.....	.....	900	2,802	3,702	0
4,285	338	4,285	.....	338	4,285	.....	.....	0	7,696	7,696	0
21,183	4,749	21,183	.....	4,749	21,183	.....	.....	17,598	51,254	67,064	41
2,685	337	1,422	1,263	496	2,346	159	924	6,024	19,743	25,143	0
3,859	274	3,084	775	413	4,665	139	1,581	9,034	44,448	52,548	0
8,310	820	8,310	0	1,094	11,544	274	3,234	5,522	83,973	88,933	0
14,854	1,431	12,816	2,038	2,003	18,555	572	5,739	20,580	166,624	166,624	0
36,037	6,180	33,999	2,038	8,763	48,998	2,583	14,999	88,808	272,968	352,636	158
36,037	6,180	33,999	2,038	8,763	48,998	2,583	14,999	89,001	273,169	353,012	158

TABLE 46.—*Mechanical power-supply equipment and fuel used*

Industry subgroup.	Character of power supply.	Size of plant (horsepower).	Establishments.		Power-supply equipment.									
						Prime movers.								
							Steam engines.		Steam turbines.		Internal-combustion engines.		Water wheels.	
			Number.	Average size (horsepower).	Aggregate horsepower.	Total horsepower.	Number.	Horsepower.	Number.	Horsepower.	Number.	Horsepower.	Number.	Horsepower.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2c. Silk goods.	No power		32											
	Steam power only:													
		1-200	82	111	9,069	9,069	95	8,719	3	350				
		201-500	41	298	12,273	12,273	55	11,068	9	1,205				
		501 and above	11	1,280	14,131	14,131	35	7,781	10	6,350				
			134	264	35,473	35,473	185	27,568	22	7,905				
	Purchased electric power only:													
		1-200	687	30	20,908									
		201-500	25	270	6,749									
		501 and above	7	749	5,243									
			719	46	32,900									
	All other power:													
		1-200	247	38	9,371	4,771	49	3,318	2	87	37	680	16	686
		201-500	26	315	8,210	5,731	40	5,394	0	0	1	12	2	325
		501 and above	32	1,655	53,107	34,077	105	23,491	10	4,167	3	635	38	5,784
			305	232	70,688	44,579	194	32,203	12	4,254	41	1,327	56	6,795
	Total power		1,158	120	139,061	80,052	379	59,771	34	12,159	41	1,327	56	6,795
	Grand total		1,190		139,061	80,052	379	59,771	34	12,159	41	1,327	56	6,795
2d. All woolen goods.	No power		13											
	Steam power only:													
		1-200	72	130	9,445	9,445	77	9,210	2	235				
		201-500	40	333	13,331	13,331	59	12,781	2	550				
		501 and above	42	2,030	85,531	85,531	96	52,147	30	33,384				
			154	700	108,307	108,307	232	74,138	34	34,169				
	Purchased electric power only:													
		1-200	82	85	6,989									
		201-500	24	319	7,663									
		501 and above	8	1,434	11,474									
			114	229	26,126									
	All other power:													
		1-200	121	104	12,657	8,804	51	4,492	1	15	9	278	77	4,019
		201-500	126	333	41,945	31,975	135	19,110	2	480	3	130	157	12,255
		501 and above	108	1,770	191,194	168,151	276	72,881	42	66,270	3	554	193	28,446
			355	692	245,796	208,930	467	96,483	45	66,765	15	962	427	44,720
	Total power		623	610	380,229	317,237	694	170,621	79	100,934	15	962	427	44,720
	Grand total		636		380,229	317,237	694	170,621	79	100,934	15	962	427	44,720
2e. Carpets and rugs.	No power		5											
	Steam power only:													
		1-200	13	134	1,748	1,748	15	1,748	0	0				
		201-500	7	334	2,335	2,335	9	2,260	1	75				
		501 and above	4	1,770	7,080	7,080	20	6,380	1	700				
			24	465	11,163	11,163	44	10,388	2	775				
	Purchased electric power only:													
		1-200	9	59	533									
		201-500	1	260	260									
		501 and above	2	1,711	3,422									
			12	351	4,215									
	All other power:													
		1-200	15	32	476	255	3	170	0	0	2	85	0	0
		201-500	7	296	2,075	1,157	7	857	0	0	0	0	1	300
		501 and above	7	2,010	14,070	13,129	18	9,167	4	2,975	0	0	6	987
			29	570	16,621	14,541	28	10,194	4	2,975	2	85	7	1,287
	Total power		65	490	31,999	25,704	72	20,582	6	3,750	2	85	7	1,287
	Grand total		70		31,999	25,704	72	40,582	6	3,750	2	85	7	1,287

by industry subgroups, by character of power supply—Continued.

Power-supply equipment—Continued.				Electric motors.				Fuel used.			
Operated by purchased energy.								Coal.			
Total horsepower.	Electric motors.		Other (horsepower).	Total.		Run by current generated in establishment.		Anthracite (long tons).	Bituminous (short tons).	Total equivalent bituminous (short tons).	Coke (short tons).
	Number.	Horsepower.		Number.	Horsepower.	Number.	Horsepower.				
16	17	18	19	20	21	22	23	24	25	26	27
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
.....	.....	.....	.....	473	1,803	473	1,803	32,182	21,020	49,820	260
.....	.....	.....	.....	1,741	3,199	1,741	3,199	46,048	13,799	55,099	0
.....	.....	.....	.....	4,880	10,263	4,880	10,263	27,226	17,244	41,644	0
.....	.....	.....	.....	7,094	15,265	7,094	15,265	105,456	52,063	146,563	260
20,908	7,348	20,908	.....	7,348	20,909	.....	.....	23,446	7,672	28,672	27
6,749	2,169	6,749	.....	2,169	6,749	.....	.....	7,212	2,434	8,934	0
5,243	1,214	5,243	.....	1,214	5,243	.....	.....	2,708	5,584	8,014	0
32,900	10,731	32,900	.....	10,731	32,900	.....	.....	33,366	15,690	45,620	27
4,600	383	1,615	2,985	557	2,130	174	515	15,008	8,847	22,347	96
2,479	569	2,479	0	812	3,008	243	529	22,074	12,570	32,370	0
19,030	5,311	19,030	0	6,437	28,912	1,126	9,882	82,636	99,148	173,648	0
26,109	6,263	23,124	2,985	7,806	34,050	1,543	10,926	119,718	120,565	120,565	228,365
59,009	16,994	56,024	2,985	25,631	82,215	8,637	26,191	258,540	188,318	420,548	383
59,009	16,994	56,024	2,985	25,631	82,215	8,637	26,191	258,569	188,958	421,214	383
.....	.....	.....	.....	.....	.....	.....	.....	10	1,060	1,069	0
.....	.....	.....	.....	94	521	94	521	7,930	60,097	67,247	45
.....	.....	.....	.....	439	2,435	439	2,435	21,367	69,234	88,434	0
.....	.....	.....	.....	2,589	51,771	2,589	51,771	64,154	268,567	326,267	0
.....	.....	.....	.....	3,122	54,727	3,122	54,727	93,154	397,898	481,948	45
6,989	912	6,989	.....	912	6,989	.....	.....	1,689	14,250	15,770	2
7,663	588	7,663	.....	588	7,663	.....	.....	1,768	14,171	15,761	877
11,474	899	11,474	.....	899	11,474	.....	.....	550	23,851	24,301	0
26,126	2,399	26,126	.....	2,399	26,126	.....	.....	4,007	52,272	55,832	879
3,853	219	2,290	1,563	382	2,834	163	544	2,054	37,083	38,933	550
9,970	968	9,420	550	1,433	14,212	465	4,792	12,327	168,116	179,216	434
23,043	2,150	23,043	0	8,140	93,264	5,990	70,221	69,663	553,688	616,488	86
36,866	3,337	34,753	2,113	9,955	110,310	6,618	75,557	84,044	758,887	834,637	1,070
62,992	5,736	60,879	2,113	15,476	191,163	9,740	130,284	181,502	1,209,057	1,372,417	1,994
62,992	5,736	60,879	2,113	15,476	191,163	9,740	130,284	181,512	1,210,117	1,373,486	1,994
.....	.....	.....	.....	.....	.....	.....	.....	178	7,054	7,212	0
.....	.....	.....	.....	37	426	37	426	1,759	11,312	12,892	0
.....	.....	.....	.....	103	524	103	524	5,712	7,096	12,246	0
.....	.....	.....	.....	388	3,494	388	3,494	19,610	23,841	41,441	0
.....	.....	.....	.....	528	4,444	528	4,444	27,081	42,249	66,579	0
533	68	533	.....	68	533	.....	.....	119	5,424	5,531	0
260	97	260	.....	97	260	.....	.....	0	497	497	0
3,422	212	3,422	.....	212	3,422	.....	.....	0	35,804	35,804	0
4,215	377	4,215	.....	377	4,215	.....	.....	119	41,725	41,832	0
221	22	221	0	22	221	0	0	1,343	1,364	2,574	0
918	218	918	0	223	993	5	75	1,140	9,828	10,858	300
941	30	941	0	1,266	8,958	1,236	8,017	6,462	123,232	129,032	0
2,080	270	2,080	0	1,511	10,172	1,241	8,092	8,945	134,424	142,464	300
6,295	647	6,295	0	2,416	18,831	1,769	12,536	36,145	218,398	250,875	300
6,295	647	6,295	0	2,416	18,831	1,769	12,536	36,323	225,452	258,087	300

TABLE 46.—*Mechanical power-supply equipment and fuel used*

Industry subgroup.	Character of power supply.	Size of plant (horsepower).	Establishments.		Power-supply equipment.										
						Prime movers.									
							Steam engines.		Steam turbines.		Internal-combustion engines.		Water wheels.	
			Number.	Average size (horsepower).	Aggregate horsepower.	Total horsepower.	Number.	Horsepower.	Number.	Horsepower.	Number.	Horsepower.	Number.	Horsepower.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2f. Dyeing and finishing.	No power		50											
	Steam power only:													
		1-200	114	77	8,803	8,803	206	8,668	8	135				
		201-500	18	345	6,237	6,237	103	5,537	3	700				
		501 and above	33	1,415	46,847	46,847	722	31,145	25	15,702				
			165	374	61,887	61,887	1,031	45,350	36	16,537				
	Purchased electric power only:													
		1-200	226	28	6,344									
		201-500	10	278	2,784									
		501 and above	1	1,131	1,131									
			237	45	10,259									
	All other power:													
		1-200	101	80	8,141	6,088	139	4,006	8	126	16	311	10	1,645
		201-500	33	318	10,560	7,501	142	6,441	0	0	2	35	12	1,025
		501 and above	29	1,780	51,673	43,441	443	18,701	31	14,425	10	1,788	49	8,527
			163	431	70,374	57,030	724	29,148	39	14,551	28	2,134	71	11,197
	Total power		565	252	142,520	118,917	1,755	74,498	75	31,088	28	2,134	71	11,197
	Grand total		615		142,520	118,917	1,755	74,498	75	31,088	28	2,134	71	11,197
2g. All other fabrics and materials.	No power		21											
	Steam power only:													
		1-200	31	98	3,054	3,054	36	3,054	0	0				
		201-500	24	314	7,503	7,503	41	7,003	1	500				
		501 and above	14	1,925	26,988	26,988	58	21,696	13	5,292				
			69	545	37,545	37,545	135	31,753	14	5,792				
	Purchased electric power only:													
		1-200	113	23	2,625									
		201-500	5	194	971									
		501 and above	3	768	2,304									
			121	49	5,900									
	All other power:													
		1-200	53	102	5,422	3,844	33	2,895	0	0	7	69	13	880
		201-500	28	297	8,333	7,082	25	3,710	0	0	2	170	30	3,202
		501 and above	21	2,230	46,878	32,698	40	9,386	5	7,875	2	227	33	15,210
			102	595	60,633	43,624	98	15,991	5	7,875	11	466	76	19,292
	Total power		292	356	104,078	81,169	233	47,744	19	13,667	11	466	76	19,292
	Grand total		313		104,078	81,169	233	47,744	19	13,667	11	466	76	19,292
2h. Clothing.	No power		1,614											
	Steam power only:													
		1-200	80	72	5,783	5,783	91	5,688	2	95				
		201-500	22	307	6,769	6,769	50	6,769	0	0				
		501 and above	3	515	1,545	1,545	11	1,535	1	10				
			105	134	14,097	14,097	152	13,992	3	105				
	Purchased electric power only:													
		1-200	12,605	4	49,332									
		201-500	4	265	1,060									
		501 and above	1	678	678									
			12,610	4	51,070									
	All other power:													
		1-200	291	23	6,632	4,269	53	2,071	1	10	179	1,608	14	580
		201-500	11	321	3,537	2,856	25	2,781	0	0	0	0	2	75
		501 and above	7	1,225	8,578	5,375	13	2,665	4	2,150	0	0	7	560
			309	61	18,747	12,500	91	7,517	5	2,160	179	1,608	23	1,215
	Total power		13,024	6	83,914	26,597	243	21,509	8	2,265	179	1,608	23	1,215
	Grand total		14,638		83,914	26,597	243	21,509	8	2,265	179	1,608	23	1,215

by industry subgroups, by character of power supply—Continued.

Power-supply equipment—Continued.				Electric motors.				Fuel used.			
Operated by purchased energy.				Total.		Run by current generated in establishment.		Coal.			
Total horsepower.	Electric motors.		Other (horsepower).					Anthracite (long tons).	Bituminous (short tons).	Total equivalent bituminous (short tons).	Coke (short tons).
	Number.	Horsepower.		Number.	Horsepower.	Number.	Horsepower.				
16	17	18	19	20	21	22	23	24	25	26	27
.....	.....	.....	.....	.....	.....	.....	.....	653	6,546	7,088	0
.....	.....	.....	.....	233	1,541	233	1,541	37,950	83,395	117,395	0
.....	.....	.....	.....	480	2,596	480	2,596	16,035	53,452	67,852	0
.....	.....	.....	.....	2,931	29,107	2,931	29,107	218,474	344,156	540,156	703
.....	.....	.....	.....	3,644	33,244	3,644	33,244	272,459	481,003	725,403	703
6,344	1,524	6,344	.....	1,524	6,344	.....	.....	21,165	41,451	60,351	226
2,784	355	2,784	.....	355	2,784	.....	.....	3,188	21,546	24,406	0
1,131	62	1,131	.....	62	1,131	.....	.....	30	8,980	9,007	0
10,259	1,941	10,259	.....	1,941	10,259	.....	.....	24,383	71,977	93,764	226
2,053	298	1,695	358	351	2,515	53	820	21,300	56,367	75,467	0
3,059	338	2,839	220	451	3,817	113	978	43,171	58,249	97,049	91
8,232	792	8,232	.....	2,297	29,819	1,505	21,587	67,535	276,931	337,531	195
13,344	1,428	12,766	578	3,099	36,151	1,671	23,385	132,006	391,547	510,047	286
23,603	3,369	23,025	578	8,684	79,654	5,315	56,629	428,848	944,527	1,329,214	1,215
23,603	3,369	23,025	578	8,684	79,654	5,315	56,629	429,501	951,073	1,336,302	1,215
.....	.....	.....	.....	.....	.....	.....	.....	1,078	0	970	6
.....	.....	.....	.....	8	216	8	216	6,003	15,133	20,535	7
.....	.....	.....	.....	317	1,957	317	1,957	18,747	29,347	46,219	0
.....	.....	.....	.....	1,100	9,398	1,100	9,398	58,195	19,538	71,918	17,408
.....	.....	.....	.....	1,425	11,571	1,425	11,571	82,945	64,018	138,672	17,415
2,625	410	2,625	.....	410	2,625	.....	.....	1,613	8,958	10,409	844
971	116	971	.....	116	971	.....	.....	0	2,487	2,487	0
2,304	104	2,304	.....	104	2,304	.....	.....	0	6,224	6,224	0
5,900	630	5,900	.....	630	5,900	.....	.....	1,613	17,669	19,120	844
1,578	181	1,315	263	234	1,463	53	148	9,084	21,795	29,967	237
1,251	99	1,251	0	136	1,704	37	453	2,695	20,950	23,330	0
14,180	559	14,180	0	1,028	29,045	469	14,865	31,761	48,918	77,484	0
17,009	839	16,746	263	1,398	32,212	559	15,466	43,540	91,663	130,781	237
22,909	1,469	22,646	263	3,453	49,683	1,984	27,037	128,098	173,350	288,573	18,496
22,909	1,469	22,646	263	3,453	49,683	1,984	27,037	129,176	173,350	289,543	18,502
.....	.....	.....	.....	.....	.....	.....	.....	2,282	415	2,465	15
.....	.....	.....	.....	482	2,023	482	2,023	17,978	21,368	37,568	0
.....	.....	.....	.....	1,534	2,662	1,534	2,662	12,463	20,437	31,537	0
.....	.....	.....	.....	294	868	294	868	572	4,670	5,185	0
.....	.....	.....	.....	2,310	5,553	2,310	5,553	31,013	46,475	74,290	0
49,332	39,645	49,332	.....	39,645	49,332	.....	.....	232,269	20,474	228,474	8,964
1,060	60	1,060	.....	60	1,060	.....	.....	511	592	1,052	0
678	49	678	.....	49	678	.....	.....	0	0	0	0
51,070	39,754	51,070	.....	39,754	51,070	.....	.....	232,780	21,066	229,526	8,964
2,363	506	1,602	761	668	2,133	162	531	6,559	11,449	17,349	369
681	189	681	0	426	1,620	237	939	3,505	15,858	19,008	0
3,203	655	3,203	0	1,231	6,328	576	3,125	3,080	34,883	37,663	0
6,247	1,350	5,486	761	2,325	10,081	975	4,595	13,144	62,190	74,020	369
57,317	41,104	56,556	761	44,389	66,704	3,285	10,148	276,937	129,731	377,836	9,333
57,317	41,104	56,556	761	44,389	66,704	3,285	10,148	279,219	130,146	380,301	9,348

TABLE 46.—*Mechanical power-supply equipment and fuel used*

Industry subgroup.	Character of power supply.	Size of plant (horsepower).	Establishments.		Power-supply equipment.									
						Prime movers.								
							Steam engines.		Steam turbines.		Internal-combustion engines.		Water wheels.	
			Number.	Average size (horsepower).	Aggregate horsepower.	Total horsepower.	Number.	Horsepower.	Number.	Horsepower.	Number.	Horsepower.	Number.	Horsepower.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
21. All other textiles.	No power		151											
	Steam power only:													
		1-200	37	103	3,797	3,797	42	3,722	1	75				
		201-500	3	329	986	986	6	720	2	266				
		501 and above	5	1,953	9,765	9,765	38	8,365	2	1,400				
			45	323	14,548	14,548	86	12,807	5	1,741				
	Purchased electric power only:													
		1-200	582	9	5,436									
		201-500	6	314	1,883									
		501 and above	5	1,013	5,064									
			593	21	12,383									
	All other power:													
		1-200	60	44	2,612	2,046	12	745	0	0	32	636	16	665
		201-500	13	385	5,000	2,992	13	2,225	2	300	0	0	4	467
		501 and above	6	2,238	13,426	3,952	71	3,950	0	0	1	2	0	0
			79	266	21,038	8,990	96	6,920	2	300	33	638	20	1,132
	Total power		717	67	47,969	23,538	182	19,727	7	2,041	33	638	20	1,132
	Grand total		868		47,969	23,538	182	19,727	7	2,041	33	638	20	1,132
3a. Blast furnaces.	Steam power only:													
		1-200	3	90	275	275	7	275	0	0				
		201-500	1	450	450	450	1	450	0	0				
		501 and above	14	5,340	74,814	74,814	189	54,694	7	20,120				
			18	4,200	75,539	75,539	197	55,419	7	20,120				
	All other power:													
		201-500	1	460	460	410	3	410	0	0	0	0	0	0
		501 and above	8	13,480	107,834	107,446	55	30,015	3	2,900	39	74,405	4	126
			9	12,030	108,294	107,856	58	30,425	3	2,900	39	74,405	4	126
	Total (power)		27	6,800	183,833	183,395	255	85,844	10	23,020	39	74,405	4	126
3b. Steel works and rolling mills.	Steam power only:													
		1-200	1	1	110	110	2	110	0	0				
		201-500	3	290	870	870	15	870	0	0				
		501 and above	40	4,630	185,261	185,261	513	151,013	44	34,248				
			44	4,240	186,241	186,241	530	151,993	44	34,248				
	Purchased electric power only:													
		1-200	10	152	1,524									
		201-500	2	356	712									
		501 and above	6	2,040	12,245									
			18	804	14,481									
	All other power:													
		1-200	3	110	331	235	4	235	0	0	0	0	0	0
		201-500	5	370	1,841	1,728	16	1,728	16	1,728	0	0	0	0
		501 and above	42	8,780	368,772	301,739	597	199,964	94	41,093	25	59,747	8	935
			50	7,418	370,944	303,703	617	201,927	94	41,093	25	59,747	8	935
	Total (power)		112	5,100	571,666	489,943	1,147	353,920	138	75,341	25	59,747	8	935
3c. Locomotives, not by railroads.	Steam power only:													
		501 and above	2	1,343	2,685	2,685	12	2,685	0	0				
	All other power:													
		501 and above	3	22,807	68,421	19,900	40	14,400	6	5,000	2	500	0	0
	Total (power)		5	14,221	71,106	22,585	52	17,085	6	5,000	2	500	0	0

by industry subgroups, by character of power supply—Continued.

Power-supply equipment—Continued.				Electric motors.				Fuel used.			
Operated by purchased energy.				Total.		Run by current generated in establishment.		Coal.			Coke (short tons).
Total horsepower.	Electric motors.		Other (horsepower).					Anthracite (long tons).	Bituminous (short tons).	Total equivalent bituminous (short tons).	
	Number.	Horsepower.		Number.	Horsepower.	Number.	Horsepower.				
16	17	18	19	20	21	22	23	24	25	26	27
.....	.....	.....	.....	.....	.....	.....	.....	309	60	338	4
.....	.....	.....	.....	96	725	96	725	6,511	16,236	22,096	1,148
.....	.....	.....	.....	205	1,145	205	1,145	1,522	23,770	25,140	1,458
.....	.....	.....	.....	776	7,102	776	7,102	14,919	79,822	93,222	1,072
.....	.....	.....	.....	1,077	8,972	1,077	8,972	22,952	119,828	140,458	3,678
5,436	2,064	5,436	.....	2,064	5,436	.....	.....	3,395	11,702	14,762	165
1,883	154	1,883	.....	154	1,883	.....	.....	344	8,495	8,805	50
5,064	396	5,064	.....	396	5,064	.....	.....	579	17,991	18,521	52
12,383	2,614	12,383	.....	2,614	12,383	.....	.....	4,318	38,188	42,088	267
566	186	399	167	186	399	0	0	1,175	2,309	3,369	0
2,008	170	2,008	0	195	2,167	25	159	8	27,838	27,845	53
9,474	594	9,474	0	597	9,481	3	7	23,582	45,505	66,705	0
12,048	950	11,881	167	978	12,047	28	166	24,765	75,652	97,919	53
24,431	3,564	24,264	167	4,669	33,402	1,105	9,138	52,035	233,668	280,465	3,998
24,431	3,564	24,264	167	4,669	33,402	1,105	9,138	52,344	233,728	280,803	4,002
.....	.....	.....	.....	2	100	2	100	0	744	744	54,977
.....	.....	.....	.....	0	0	0	0	0	1,500	1,500	75,000
.....	.....	.....	.....	407	16,513	407	16,513	27,330	209,196	233,696	1,366,358
.....	.....	.....	.....	409	16,613	409	16,613	27,330	211,440	235,940	1,496,335
50	1	50	0	1	50	0	0	0	1,400	1,400	70,000
388	8	388	0	306	65,055	298	64,667	13,186	60,614	72,414	1,604,486
438	9	438	0	307	65,105	298	64,667	13,186	62,014	73,814	1,674,486
438	9	438	0	716	81,718	707	81,280	40,516	273,454	309,754	3,170,821
.....	.....	.....	.....	1	15	1	15	0	556	556	0
.....	.....	.....	.....	101	1,480	101	1,480	148	23,540	23,674	3,497
.....	.....	.....	.....	4,203	83,349	4,203	83,349	101,584	1,434,581	1,526,007	19,507
.....	.....	.....	.....	4,305	84,844	4,305	84,844	101,732	1,458,677	1,550,237	23,004
1,524	79	1,524	.....	79	1,524	.....	.....	141	1,417	1,543	276
712	62	712	.....	62	712	.....	.....	81	73	146	0
12,245	327	12,245	.....	327	12,245	.....	.....	952	19,302	20,157	2,174
14,481	468	14,481	.....	468	14,481	.....	.....	1,174	20,792	21,846	2,450
96	13	96	0	13	96	0	0	0	2,400	2,400	2,000
113	11	113	0	55	357	44	244	150	19,920	20,065	926
67,033	5,583	66,783	250	18,236	412,418	12,853	345,635	418,215	2,047,270	2,423,668	60,313
67,242	5,607	66,992	250	18,304	412,871	12,697	345,635	418,365	2,069,590	2,446,123	63,244
81,723	6,075	81,473	250	23,077	512,196	17,002	430,723	521,271	3,549,059	4,018,206	88,698
.....	.....	.....	.....	264	11,531	264	11,531	23,178	6,994	27,794	1,602
48,521	2,396	48,521	0	3,660	73,835	1,264	25,314	9,620	209,735	218,385	18,778
48,521	2,396	48,521	0	3,924	85,366	1,528	36,845	32,798	216,628	246,179	20,380

TABLE 46.—*Mechanical power-supply equipment and fuel used*

Industry subgroup.	Character of power supply.	Size of plant (horsepower).	Establishments.		Power-supply equipment.									
						Prime movers.								
			Number.	Average size (horsepower).	Aggregate horsepower.	Total horsepower.	Steam engines.		Steam turbines.		Internal-combustion engines.		Water wheels.	
							Number.	Horsepower.	Number.	Horsepower.	Number.	Horsepower.	Number.	Horsepower.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
3d. All other iron and steel products.	No power		407											
	Steam power only:													
		1-200	452	71	32,166	32,166	535	31,713	9	453				
		201-500	87	333	29,030	29,030	174	27,045	16	1,985				
		501 and above	72	1,920	138,052	138,052	337	70,878	79	67,174				
			611	326	199,248	199,248	1,046	129,636	104	69,612				
	Purchased electric power only:													
		1-200	3,701	26	95,580									
		201-500	142	312	44,489									
		501 and above	103	1,050	118,676									
			3,946	655	258,745									
	All other power:													
		1-200	1,341	40	54,293	38,753	319	16,741	7	286	960	15,827	167	5,899
		201-500	165	320	52,501	32,872	215	24,089	12	785	56	2,978	75	5,040
		501 and above	155	2,290	354,363	208,708	465	111,465	54	77,578	63	10,622	71	9,043
			1,661	278	461,157	280,333	999	152,275	73	78,649	1,079	29,427	313	19,982
	Total power		6,218	148	919,150	479,581	2,045	281,911	177	148,261	1,079	29,427	313	19,982
	Grand total		6,625		919,150	479,581	2,045	281,911	177	148,261	1,079	29,427	313	19,982
4a. Lumber.	No power		107											
	Steam power only:													
		1-200	1,090	38	41,477	41,477	1,189	41,117	8	360				
		201-500	9	314	2,827	2,827	18	2,827	0	0				
			1,099	40	44,304	44,304	1,207	43,944	8	360				
	Purchased electric power only:													
		1-200	54	46	2,475									
		201-500	2	378	757									
			56	58	3,232									
	All other power:													
		1-200	466	44	20,476	19,681	103	4,032	1	25	211	4,557	364	11,067
		201-500	15	278	4,179	3,407	16	2,260	0	0	9	423	14	724
		501 and above	5	806	4,031	3,896	54	2,786	2	700	3	10	2	400
			486	59	28,686	26,984	173	9,078	3	725	223	4,990	380	12,191
	Total power		1,641	46	76,222	71,288	1,380	53,022	11	1,085	223	4,990	380	12,191
	Grand total		1,748		76,222	71,288	1,380	53,022	11	1,085	223	4,990	380	12,191
1b. Furniture and all other lumber products.	No power		803											
	Steam power only:													
		1-200	509	84	42,695	42,695	549	42,255	5	440				
		201-500	81	303	24,502	24,502	121	24,242	2	260				
		501 and above	24	890	21,340	21,340	77	17,835	8	3,505				
			614	144	88,537	88,537	747	84,332	15	4,205				
	Purchased electric power only:													
		1-200	1,621	24	39,653									
		201-500	30	196	8,867									
		501 and above	4	743	2,973									
			1,655	31	51,493									
	All other power:													
		1-200	723	44	32,072	23,888	225	13,524	2	30	327	4,834	178	5,500
		201-500	60	296	17,764	12,372	84	10,859	0	0	5	114	27	1,399
		501 and above	17	845	14,445	10,320	57	9,548	1	150	2	9	6	613
			800	80	64,281	46,580	366	33,931	3	180	334	4,957	211	7,512
	Total power		3,069	66	204,311	135,117	1,113	118,263	18	4,385	334	4,957	211	7,512
	Grand total		3,872		204,311	135,117	1,113	118,263	18	4,385	334	4,957	211	7,512

by industry subgroups, by character of power supply—Continued.

Power-supply equipment—Continued.				Electric motors.				Fuel used.			
Operated by purchased energy.				Total.		Run by current generated in establishment.		Coal.			Coke (short tons).
Total horsepower.	Electric motors.		Other (horsepower).					Anthracite (long tons).	Bituminous (short tons).	Total equivalent bituminous (short tons).	
	Number.	Horsepower.		Number.	Horsepower.	Number.	Horsepower.				
16	17	18	19	20	21	22	23	24	25	26	27
.....	.....	.....	.....	.....	.....	.....	.....	4,230	3,304	7,114	1,077
.....	.....	.....	.....	1,213	8,713	1,213	8,713	69,628	153,924	216,564	48,561
.....	.....	.....	.....	1,900	19,738	1,900	19,738	40,664	105,987	141,987	24,465
.....	.....	.....	.....	9,491	133,800	9,491	133,800	243,808	598,265	817,865	113,638
.....	.....	.....	.....	12,604	162,251	12,604	162,251	354,100	858,176	1,176,416	186,664
95,580	13,971	95,580	.....	13,971	95,580	.....	.....	66,177	102,742	162,242	109,625
44,489	4,158	44,489	.....	4,158	44,489	.....	.....	24,835	58,478	80,778	31,114
118,676	10,144	118,676	.....	10,144	118,676	.....	.....	32,453	147,478	176,578	63,708
258,745	28,273	258,745	.....	28,273	258,745	.....	.....	123,465	308,698	419,598	204,447
15,540	1,654	13,033	2,507	2,331	17,617	677	4,584	43,195	101,056	140,056	38,735
19,629	1,726	19,454	175	2,686	30,564	960	11,110	40,088	137,558	173,558	39,182
145,655	9,093	145,455	200	14,068	206,497	4,975	61,042	152,280	931,306	1,068,000	95,199
180,824	12,473	177,942	2,882	19,085	254,678	6,612	76,736	235,563	1,169,920	1,381,614	173,116
439,569	40,746	436,687	2,882	59,962	675,674	19,216	238,987	713,128	2,336,794	2,977,628	564,227
439,569	40,746	436,687	2,882	59,962	675,674	19,216	238,987	717,358	2,340,098	2,984,744	565,304
.....	.....	.....	.....	.....	.....	.....	.....	0	1,105	1,105	0
.....	.....	.....	.....	10	65	10	65	1,012	2,183	3,090	20
.....	.....	.....	.....	20	415	20	415	0	1,897	1,897	89
.....	.....	.....	.....	30	480	30	480	1,012	4,080	4,987	109
2,475	116	2,475	.....	116	2,475	.....	.....	11	100	110	0
757	64	757	.....	64	757	.....	.....	0	0	0	0
3,232	180	3,232	.....	180	3,232	.....	.....	11	100	110	0
795	39	730	65	45	750	6	20	109	184	292	0
772	99	772	0	135	1,052	36	280	0	1,705	1,705	0
135	13	135	0	146	2,341	133	2,206	25	12,054	12,076	166
1,702	151	1,637	65	326	4,143	175	2,506	134	13,943	14,073	166
4,934	331	4,869	65	536	7,855	205	2,986	1,157	18,123	19,170	275
4,934	331	4,869	65	536	7,855	205	2,986	1,157	19,228	20,275	275
.....	.....	.....	.....	.....	.....	.....	.....	3,096	1,405	4,195	1
.....	.....	.....	.....	409	3,186	409	3,186	35,521	75,896	107,864	864
.....	.....	.....	.....	1,100	9,068	1,100	9,068	6,057	87,439	92,894	1,220
.....	.....	.....	.....	888	9,661	888	9,661	4,665	44,477	48,675	1,242
.....	.....	.....	.....	2,397	21,915	2,397	21,915	46,243	207,812	249,433	3,326
39,653	6,406	39,653	.....	6,406	39,653	.....	.....	13,779	13,524	25,926	1,636
8,867	961	8,867	.....	961	8,867	.....	.....	897	1,629	2,437	3,099
2,973	320	2,973	.....	320	2,973	.....	.....	870	2,294	3,077	0
51,493	7,687	51,493	.....	7,687	51,493	.....	.....	15,546	17,447	31,440	4,735
8,184	864	5,114	3,070	1,098	6,608	234	1,494	9,962	31,947	40,947	1,141
5,392	504	5,142	250	823	7,910	319	2,768	3,262	25,239	28,174	1,678
4,125	318	4,125	0	722	7,937	404	3,812	7,215	41,888	48,379	0
17,701	1,686	14,381	3,320	2,643	22,455	957	8,074	20,439	99,074	117,500	2,819
69,194	9,373	65,874	3,320	12,727	95,863	3,354	29,989	82,228	324,333	398,373	10,880
69,194	9,373	65,874	3,320	17,727	95,863	3,354	29,989	85,324	325,738	402,568	10,881

TABLE 46.—*Mechanical power-supply equipment and fuel used*

Industry subgroup.	Character of power supply.	Size of plant (horsepower).	Establishments.		Power-supply equipment.									
						Prime movers.								
							Steam engines.		Steam turbines.		Internal-combustion engines.		Water wheels.	
			Number.	Average size (horsepower).	Aggregate horsepower.	Total horsepower.	Number.	Horsepower.	Number.	Horsepower.	Number.	Horsepower.	Number.	Horsepower.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
5a. Leather, tanned, curried, and finished.		No power	14											
		1-200	69	98	6,710	6,710	82	6,510	4	200				
		201-500	27	291	7,895	7,895	56	7,595	3	300				
		501 and above	17	1,280	21,784	21,784	49	13,147	15	8,637				
			113	322	36,389	36,389	187	27,252	22	9,137				
		Purchased electric power only:												
		1-200	94	55	5,123									
		201-500	12	383	4,603									
		501 and above	2	586	1,173									
			108	101	10,899									
		All other power:												
		1-200	63	96	6,061	4,230	55	4,017	0	0	5	73	3	140
		201-500	50	295	14,772	9,819	82	9,155	0	0	3	335	4	329
		501 and above	18	1,100	19,808	8,047	32	7,500	0	0	1	20	5	527
			131	310	40,641	22,096	169	20,672	0	0	9	428	12	996
		Total power	352	250	87,929	58,485	356	47,924	22	9,137	9	428	12	996
		Grand total	366		87,929	58,485	356	47,924	22	9,137	9	428	12	996
5b. Leather finished products.		No power	521											
		Steam power only:												
		1-200	151	84	12,629	12,629	163	12,629	0	0				
		201-500	19	320	6,095	6,095	32	6,055	1	40				
		501 and above	8	1,827	14,620	14,620	19	5,025	10	9,595				
			178	187	33,344	33,344	214	23,709	11	9,635				
		Purchased electric power only:												
		1-200	1,750	11	18,799									
		201-500	20	293	5,863									
		501 and above	5	1,058	5,289									
			1,775	17	29,951									
		All other power:												
		1-200	367	33	12,174	3,522	44	2,488	0	0	75	871	9	163
		201-500	30	312	9,352	6,605	38	4,670	7	1,355	0	0	6	580
		501 and above	5	1,066	5,331	2,505	11	2,505	0	0	0	0	0	0
			402	67	26,857	12,632	93	9,663	7	1,355	75	871	15	743
		Total power	2,355	38	90,152	45,976	307	33,372	18	10,990	75	871	15	743
		Grand total	2,876		90,152	45,976	307	33,372	18	10,990	75	871	15	743
6a. Paper and wood pulp.		Steam power only:												
		1-200	10	172	1,720	1,720	18	1,720	0	0				
		201-500	17	345	5,876	5,876	46	5,376	2	500				
		501 and above	33	2,050	67,879	67,879	251	52,461	20	15,418				
			60	1,258	75,475	75,475	315	59,557	22	15,918				
		Purchased electric power only:												
		1-200	3	136	409									
		201-500	3	347	1,040									
		501 and above	5	1,009	5,047									
			11	590	6,496									
		All other power:												
		1-200	33	204	6,737	6,624	55	4,204	0	0	0	0	50	2,420
		201-500	55	338	18,596	16,023	82	9,208	1	150	4	50	89	6,615
		501 and above	138	2,700	374,782	327,901	633	111,858	38	21,988	11	1,746	543	192,309
			226	1,770	400,115	350,548	770	125,270	39	22,138	15	1,796	682	201,344
		Total power	297	1,620	482,086	426,023	1,085	184,827	61	38,056	15	1,796	682	201,344

by industry subgroups, by character of power supply—Continued.

Power-supply equipment—Continued.				Electric motors.				Fuel used.			
Operated by purchased energy.				Total.		Run by current generated in establishment.		Coal.			Coke (short tons).
Total horsepower.	Electric motors.		Other (horsepower).					Anthracite (long tons).	Bituminous (short tons).	Total equivalent bituminous (short tons).	
	Number.	Horsepower.		Number.	Horsepower.	Number.	Horsepower.				
16	17	18	19	20	21	22	23	24	25	26	27
.....	.....	.....	.....	.....	.....	.....	.....	925	762	1,594	94
.....	.....	.....	.....	60	713	60	713	3,916	30,564	34,092	0
.....	.....	.....	.....	96	937	96	937	9,871	62,323	71,323	0
.....	.....	.....	.....	1,698	23,541	1,698	23,541	26,609	170,468	194,417	58
.....	.....	.....	.....	1,854	25,191	1,854	25,191	40,396	263,355	299,832	58
5,123	603	5,123	.....	603	5,123	.....	.....	2,586	20,505	22,835	2,000
4,603	337	4,603	.....	337	4,603	.....	.....	497	21,270	21,720	200
1,173	32	1,173	.....	32	1,173	.....	.....	0	1,802	1,802	0
10,899	972	10,899	.....	972	10,899	.....	.....	3,083	43,577	46,357	2,200
1,831	130	1,468	363	175	2,006	45	538	4,243	22,795	26,611	
4,953	354	4,953	0	483	6,656	129	1,703	14,558	53,215	66,319	60
11,761	545	11,761	0	810	14,344	265	2,583	14,943	47,673	61,119	8
18,545	1,029	18,182	363	1,468	23,006	439	4,824	33,744	123,683	154,049	68
29,444	2,001	29,081	363	4,294	59,096	2,293	30,015	77,223	430,615	500,238	2,326
29,444	2,001	29,081	363	4,294	59,096	2,293	30,015	78,148	431,377	501,832	2,420
.....	.....	.....	.....	.....	.....	.....	.....	1,153	470	1,505	1
.....	.....	.....	.....	456	2,409	456	2,409	17,223	44,372	59,872	443
.....	.....	.....	.....	403	2,701	403	2,701	8,422	13,427	20,987	0
.....	.....	.....	.....	1,838	9,948	1,838	9,948	12,029	62,528	73,328	0
.....	.....	.....	.....	2,697	15,058	2,697	15,058	37,674	120,327	154,187	443
18,799	5,007	18,799	.....	5,007	18,799	.....	.....	15,352	26,721	40,621	207
5,863	1,215	5,863	.....	1,215	5,863	.....	.....	3,852	11,317	14,777	0
5,289	607	5,289	.....	607	5,289	.....	.....	1,885	7,340	9,030	0
29,951	6,829	29,951	.....	6,829	29,951	.....	.....	21,089	45,378	64,428	207
8,652	605	2,650	6,002	675	2,946	70	296	2,715	13,143	15,408	195
2,747	533	2,747	0	649	3,612	116	865	3,680	27,793	31,103	0
2,826	308	2,826	0	333	3,283	25	457	2,896	8,642	11,242	0
14,225	1,446	8,223	6,002	1,657	9,841	211	1,618	9,291	49,578	57,748	195
44,176	8,275	38,174	6,002	11,183	54,850	2,908	16,676	68,054	215,283	276,363	845
44,176	8,275	38,174	6,002	11,183	54,850	2,908	16,676	69,207	215,753	277,868	846
.....	.....	.....	.....	2	159	2	159	5,175	4,968	9,618	0
.....	.....	.....	.....	34	1,013	34	1,013	8,871	73,891	81,851	0
.....	.....	.....	.....	757	11,392	757	11,392	36,313	677,183	709,783	1,318
.....	.....	.....	.....	793	12,564	793	12,564	50,359	756,042	801,252	1,318
409	39	409	.....	39	409	.....	.....	4,264	2,000	5,840	0
1,040	26	1,040	.....	26	1,040	.....	.....	652	2,555	3,140	0
5,047	102	5,047	.....	102	5,047	.....	.....	0	31,788	31,788	0
6,496	167	6,496	.....	167	6,496	.....	.....	4,916	36,343	40,768	0
113	6	113	0	19	255	13	142	11,613	35,348	45,848	0
2,573	124	2,573	0	174	3,366	50	793	15,851	78,855	93,055	522
46,881	1,542	45,371	1,510	3,202	89,697	1,660	44,326	463,652	849,164	1,266,164	8,173
49,567	1,672	48,057	1,510	3,395	93,318	1,723	45,261	491,116	963,367	1,405,067	8,695
56,063	1,839	54,553	1,510	4,355	112,378	2,516	57,825	546,391	1,755,752	2,247,067	10,013

TABLE 46.—*Mechanical power-supply equipment and fuel used*

Industry subgroup.	Character of power supply.	Size of plant (horsepower).	Establishments.		Power-supply equipment.									
						Prime movers.								
			Number.	Average size (horsepower).	Aggregate horsepower.	Total horsepower.	Steam engines.		Steam turbines.		Internal-combustion engines.		Water wheels.	
							Number.	Horsepower.	Number.	Horsepower.	Number.	Horsepower.	Number.	Horsepower.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
6b. Manufactures of paper.	No power		95											
	Steam power only:													
		1-200	50	63	3,164	3,164	52	3,024	2	140				
		201-500	13	312	4,055	4,055	25	4,055	0	0				
		501 and above	11	1,303	14,329	14,329	32	7,557	16	6,772				
			74	290	21,548	21,548	109	14,636	18	6,912				
	Purchased electric power only:													
		1-200	807	18	14,195									
		201-500	10	303	3,028									
		501 and above	1	846	846									
			818	22	18,069									
	All other power:													
		1-200	129	37	4,758	3,364	34	1,931	0	0	64	919	12	514
		201-500	12	337	4,048	2,630	15	1,956	1	35	1	4	7	635
		501 and above	5	1,493	7,464	4,501	11	2,651	1	1,500	0	0	3	350
			146	112	16,270	10,495	60	6,538	2	1,535	65	923	22	1,499
	Total power		1,038	54	55,887	32,043	169	21,174	20	8,447	65	923	22	1,499
	Grand total		1,133		55,887	32,043	169	21,174	20	8,447	65	923	22	1,499
6c. Printing and publishing.	No power		2,504											
	Steam power only:													
		1-200	55	53	2,927	2,927	60	2,917	1	10				
		201-500	14	312	4,371	4,371	30	4,146	1	225				
		501 and above	12	1,150	13,794	13,794	47	13,574	2	220				
			81	261	21,092	21,092	137	20,637	4	455				
	Purchased electric power only:													
		1-200	6,333	15	97,799									
		201-500	42	297	12,531									
		501 and above	17	1,040	17,781									
			6,392	20	128,111									
	All other power:													
		1-200	462	17	7,980	4,953	46	2,453	2	42	333	2,171	16	287
		201-500	12	273	3,284	1,560	10	965	0	0	5	195	8	400
		501 and above	9	888	7,989	4,105	28	3,805	1	200	1	100	0	0
			483	40	19,253	10,618	84	7,223	3	242	339	2,466	24	687
	Total power		6,956	24	168,456	31,710	221	27,860	7	697	339	2,466	24	687
	Grand total		9,460		168,456	31,710	221	27,860	7	697	339	2,466	24	687
7. Liquors and beverages.	No power		121											
	Steam power only:													
		1-200	77	87	6,715	6,715	150	6,570	2	145				
		201-500	37	338	12,515	12,515	198	12,027	6	488				
		501 and above	46	1,245	57,296	57,296	390	55,502	15	1,794				
			160	480	76,526	76,526	738	74,099	23	2,427				
	Purchased electric power only:													
		1-200	915	5	4,954									
		501 and above	1	525	525									
			916	6	5,479									
	All other power:													
		1-200	170	34	5,826	4,544	115	3,958	1	5	96	554	20	27
		201-500	40	327	13,071	10,841	234	10,490	2	150	6	160	13	41
		501 and above	17	770	13,032	9,851	138	9,245	3	6	0	0	1	600
			227	140	31,929	25,236	487	23,693	6	161	102	714	34	668
	Total power		1,303	88	113,934	101,762	1,225	97,792	29	2,588	102	714	34	668
	Grand total		1,424		113,934	101,762	1,225	97,792	29	2,588	102	714	34	668

by industry subgroups, by character of power supply—Continued.

Power-supply equipment—Continued.				Electric motors.				Fuel used.			
Operated by purchased energy.				Total.		Run by current generated in establishment.		Coal.			Coke (short tons).
Total horsepower.	Electric motors.		Other (horsepower).					Anthracite (long tons).	Bituminous (short tons).	Total equivalent bituminous (short tons).	
	Number.	Horsepower.		Number.	Horsepower.	Number.	Horsepower.				
16	17	18	19	20	21	22	23	24	25	26	27
.....	.....	.....	.....	.....	.....	.....	.....	155	301	441	0
.....	.....	.....	.....	188	786	188	786	8,502	10,895	18,545	200
.....	.....	.....	.....	800	2,727	800	2,727	7,896	13,604	20,704	0
.....	.....	.....	.....	1,551	9,338	1,551	9,338	36,131	47,028	79,528	576
.....	.....	.....	.....	2,539	12,851	2,539	12,851	52,529	71,527	118,777	776
14,195	5,028	14,195	.....	5,028	14,195	.....	.....	10,177	19,755	28,955	89
3,028	478	3,028	.....	478	3,028	.....	.....	590	2,837	3,367	75
846	56	846	.....	56	846	.....	.....	0	0	0	0
18,069	5,562	18,069	.....	5,562	18,069	.....	.....	10,767	22,592	32,322	164
1,394	228	1,018	376	461	1,525	233	507	4,403	9,503	13,463	3
1,418	326	1,418	0	528	2,030	202	612	1,167	7,972	9,022	370
2,963	206	2,963	0	256	3,618	50	655	2,359	12,343	14,463	0
5,775	760	5,399	376	1,245	7,173	485	1,774	7,929	29,818	36,948	373
23,844	6,322	23,468	376	9,346	38,093	3,024	14,625	71,225	123,937	188,047	1,313
23,844	6,322	23,468	376	9,346	38,093	3,024	14,625	71,380	124,238	188,488	1,313
.....	.....	.....	.....	.....	.....	.....	.....	2,735	414	2,874	4
.....	.....	.....	.....	136	433	136	433	9,098	8,934	17,114	0
.....	.....	.....	.....	814	3,718	814	3,718	12,513	9,887	21,172	1,500
.....	.....	.....	.....	2,318	10,865	2,318	10,865	35,672	17,525	50,225	0
.....	.....	.....	.....	3,268	15,016	3,268	15,016	57,283	36,346	88,511	1,500
97,799	36,517	97,799	.....	36,517	97,799	.....	.....	37,447	14,867	46,867	343
12,531	3,236	12,531	.....	3,236	12,531	.....	.....	4,366	1,332	5,257	0
17,781	2,786	17,781	.....	2,786	17,781	.....	.....	12,402	1,554	12,724	0
128,111	42,539	128,111	.....	42,539	128,111	.....	.....	54,215	17,753	64,848	343
3,027	650	2,403	624	776	2,601	126	198	10,275	6,381	15,631	3
1,724	411	1,724	0	474	1,924	63	200	6,763	2,915	9,005	2
3,884	1,070	3,884	0	2,563	8,165	1,493	4,281	16,217	10,617	25,227	0
8,635	2,131	8,011	624	3,813	12,690	1,682	4,679	33,255	19,913	49,863	5
136,746	44,670	136,122	624	49,620	155,817	4,950	19,695	144,753	74,012	203,222	1,848
136,746	44,670	136,122	624	49,620	155,817	4,950	19,695	147,488	74,486	206,096	1,852
.....	.....	.....	.....	.....	.....	.....	.....	493	2,610	3,053	0
.....	.....	.....	.....	254	1,221	254	1,221	44,665	36,511	76,711	16
.....	.....	.....	.....	634	3,318	634	3,318	33,910	55,811	86,311	869
.....	.....	.....	.....	1,769	12,233	1,769	12,233	140,003	174,410	300,410	989
.....	.....	.....	.....	2,657	16,772	2,657	16,772	218,578	266,732	463,432	1,879
4,954	2,062	4,954	.....	2,062	4,954	.....	.....	10,696	17,519	26,869	2,267
525	58	525	.....	58	525	.....	.....	0	3,654	3,654	0
5,479	2,120	5,479	.....	2,120	5,479	.....	.....	10,696	21,173	30,523	2,267
1,282	289	1,273	9	297	1,302	8	29	29,389	27,058	53,358	0
2,230	368	1,960	270	483	2,658	115	698	45,732	40,098	81,298	0
3,181	340	3,181	0	489	4,455	149	1,274	40,200	38,388	74,588	999
6,693	997	6,414	279	1,269	8,415	272	2,001	115,321	105,544	209,244	999
12,172	3,117	11,893	279	6,046	30,666	2,929	18,773	344,595	393,449	703,199	5,140
12,172	3,117	11,893	279	6,046	30,666	2,929	18,773	345,088	396,059	706,252	5,140

TABLE 46.—*Mechanical power-supply equipment and fuel used*

Industry subgroup.	Character of power supply.	Size of plant (horsepower).	Establishments.		Power-supply equipment.									
						Prime movers.								
							Steam engines.		Steam turbines.		Internal-combustion engines.		Water wheels.	
			Number.	Average size (horsepower).	Aggregate horsepower.	Total horsepower.	Number.	Horsepower.	Number.	Horsepower.	Number.	Horsepower.	Number.	Horsepower.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
8a. Coke, not including gas-house coke.	Steam power only:	301-500	1	405	405	405	8	405	0	0				
		501 and above	4	4,289	17,157	17,157	63	7,587	38	9,570				
			5	3,512	17,562	17,562	71	7,992	38	9,570				
	Purchased electric power only:	501 and above	3	4,255	12,765									
	Other power:	501 and above	2	4,710	9,419	3,170	44	1,450	15	1,720	0	0	0	0
		Total power	10	3,975	39,746	20,732	115	9,442	53	11,290	0	0	0	0
8b. Explosives.	Steam power only:	1-200	2	74	148	148	3	140	1	8				
		201-500	4	378	1,513	1,513	19	1,495	3	18				
		501 and above	7	1,676	11,738	11,738	32	4,910	14	6,828				
			13	1,033	13,399	13,399	54	6,545	18	6,854				
	Purchased electric power only:	1-200	1	10	10									
		201-500	2	310	620									
		501 and above	1	2,142	2,142									
			4	693	2,772									
	All other power:	1-200	1	181	181	20	2	20	0	0	0	0	0	0
		201-500	3	267	801	480	24	395	1	30	1	14	3	41
		501 and above	2	1,185	2,369	2,150	7	1,112	1	330	0	0	22	708
			6	559	3,351	2,650	33	1,527	2	360	1	14	25	749
		Total power	23	850	19,522	16,049	87	8,072	20	7,214	1	14	25	749
8c. Gas, illuminating and heating.	No power		63											
	Steam power only:	1-200	88	61	5,360	5,360	187	4,055	46	1,305				
		201-500	14	369	5,162	5,162	62	3,223	28	1,939				
		501 and above	26	1,650	43,103	43,103	484	34,090	79	9,013				
			128	420	53,625	53,625	733	41,368	153	12,257				
	Purchased electric power only:	1-200	17	43	726									
		201-500	2	313	625									
			19	72	1,351									
	All other power:	1-200	34	74	2,533	1,767	44	811	28	876	6	66	1	14
		201-500	7	377	2,636	2,049	51	1,225	16	814	1	10	0	0
		501 and above	14	3,430	48,052	46,351	503	32,068	207	11,343	26	2,940	0	0
			55	970	53,221	50,167	598	34,104	251	13,033	33	3,016	1	14
		Total power	202	540	108,197	103,792	1,331	75,472	404	25,290	33	3,106	1	14
		Grand total	265		108,197	103,792	1,331	75,472	404	25,290	33	3,016	1	14
8d. Petroleum refining.	Steam power only:	1-200	1	75	75	75	7	73	1	2				
		201-500	3	349	1,048	1,048	29	1,048						
		501 and above	5	4,806	24,031	24,031	292	13,271	23	10,760				
			9	2,795	25,154	25,154	328	14,392	24	10,762				
	Purchased electric power only:	1-200	4	39	147									
	All other power:	201-500	1	374	374	374	17	372	0	0	1	2	0	0
		501 and above	7	5,835	40,842	39,492	364	14,892	53	12,396	25	12,204	0	0
			8	5,152	41,216	39,866	381	15,264	53	12,396	26	12,206	0	0
		Total power	21	3,167	66,517	65,020	709	29,656	77	23,158	26	12,206	0	0

by industry subgroups, by character of power supply—Continued.

Power-supply equipment—Continued.				Electric motors.				Fuel used.			
Operated by purchased energy.				Total.		Run by current generated in establishment.		Coal.			Coke (short tons).
Total horsepower.	Electric motors.		Other (horsepower).					Anthracite (long tons).	Bituminous (short tons).	Total equivalent bituminous (short tons).	
	Number.	Horsepower.		Number.	Horsepower.	Number.	Horsepower.				
16	17	18	19	20	21	22	23	24	25	26	27
.....	.....	.....	.....	62	1,711	62	1,711	0	181,066	181,066	0
.....	.....	.....	.....	356	12,641	356	12,641	3,113	1,431,323	1,434,122	36,945
.....	.....	.....	.....	418	14,352	418	14,352	3,113	1,612,389	1,615,188	36,945
12,765	316	12,765	.....	316	12,765	.....	.....	500	1,406,938	1,407,388	0
6,249	154	6,249	0	213	7,124	59	875	464	1,000,443	1,000,860	0
19,014	470	19,014	0	947	34,241	477	15,227	4,077	4,019,770	4,023,436	36,945
.....	.....	.....	.....	0	0	0	0	792	0	713	0
.....	.....	.....	.....	328	1,431	328	1,431	9,543	57,983	66,533	0
.....	.....	.....	.....	670	11,068	670	11,068	21,234	180,102	199,202	0
.....	.....	.....	.....	998	12,499	998	12,499	31,569	238,085	266,448	0
10	2	10	.....	2	10	.....	.....	0	10	10	0
620	42	620	.....	42	620	.....	.....	2,135	45	1,955	0
2,142	78	2,142	.....	78	2,142	.....	.....	0	4,700	4,700	0
2,772	122	2,772	.....	122	2,772	.....	.....	2,135	4,755	6,665	0
161	9	161	0	9	161	0	0	226	0	203	0
321	13	321	0	14	336	1	15	6,119	5,000	10,500	0
219	11	219	0	46	807	35	588	108	3,576	3,673	0
701	33	701	0	69	1,304	36	603	6,453	8,576	14,376	0
3,473	155	3,473	0	1,189	16,575	1,034	13,102	40,157	251,416	287,489	0
.....	.....	.....	.....	.....	.....	.....	.....	61,526	225,348	280,548	3,146
.....	.....	.....	.....	53	819	53	819	79,958	109,818	180,616	17,611
.....	.....	.....	.....	21	210	21	210	68,757	96,096	157,896	7,938
.....	.....	.....	.....	296	4,000	296	4,000	423,775	1,045,529	1,425,529	228,741
.....	.....	.....	.....	370	5,029	370	5,029	572,490	1,250,443	1,764,041	254,290
726	55	726	.....	55	726	.....	.....	10,798	95,521	105,121	26,125
625	31	625	.....	31	625	.....	.....	8,652	149,341	157,091	1,810
1,351	86	1,351	.....	86	1,351	.....	.....	19,450	244,862	262,212	27,935
766	54	753	13	79	1,008	25	255	46,742	98,952	140,952	10,634
587	48	587	0	48	587	0	0	753	170,413	171,090	1,427
1,701	225	1,701	0	420	4,900	195	3,199	528,141	409,365	883,365	311,197
3,054	327	3,041	13	547	6,495	220	3,454	575,636	678,730	1,195,407	323,258
4,405	413	4,392	13	1,003	12,875	590	8,483	1,167,576	2,174,035	3,221,660	605,483
4,405	413	4,392	13	1,003	12,875	590	8,483	1,229,102	2,399,383	3,502,208	608,629
.....	.....	.....	.....	5	21	5	21	0	0	0	0
.....	.....	.....	.....	104	1,204	104	1,204	11,062	69,536	79,492	0
.....	.....	.....	.....	231	4,936	231	4,936	395,366	122,396	478,225	44,479
.....	.....	.....	.....	340	6,161	340	6,161	406,428	191,932	557,717	44,479
147	19	147	.....	19	147	.....	.....	0	0	0	0
0	0	0	0	0	0	0	0	6,000	3,000	8,400	0
1,350	29	1,350	0	766	19,333	737	17,983	625,225	193,981	756,683	177,677
1,350	29	1,350	0	766	19,333	737	17,983	631,225	196,981	765,083	177,677
1,497	48	1,497	0	1,125	25,641	1,077	24,144	1,037,653	388,913	1,322,800	222,156

TABLE 46.—*Mechanical power-supply equipment and fuel used*

Industry subgroup.	Character of power supply.	Size of plant (horsepower).	Establishments.		Power-supply equipment.									
						Prime movers.								
			Number.	Average size (horsepower).	Aggregate horsepower.	Total horsepower.	Steam engines.		Steam turbines.		Internal-combustion engines.		Water wheels.	
							Number.	Horsepower.	Number.	Horsepower.	Number.	Horsepower.	Number.	Horsepower.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
8c. All other chemicals.	No power		1,064	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	Steam power only:													
		1-200	344	63	21,714	21,714	497	21,620	7	94	.....	.....	.....	.....
		201-500	69	328	22,756	22,756	198	20,656	11	2,100	.....	.....	.....	.....
		501 and above	53	1,480	78,476	78,476	379	49,196	81	29,280	.....	.....	.....	.....
			466	262	122,946	122,946	1,074	91,472	99	31,474	.....	.....	.....	.....
	Purchased electric power only:													
		1-200	943	22	20,788	.....	.....	.....	.....	.....	.....	.....	.....	.....
		201-500	41	312	12,805	.....	.....	.....	.....	.....	.....	.....	.....	.....
		501 and above	19	1,180	22,488	.....	.....	.....	.....	.....	.....	.....	.....	.....
			1,003	56	56,081	.....	.....	.....	.....	.....	.....	.....	.....	.....
	All other power:													
		1-200	281	52	14,674	9,194	187	6,225	7	346	134	2,237	16	386
		201-500	49	321	15,733	9,698	121	8,028	2	225	26	615	8	830
		501 and above	54	1,490	80,433	43,127	459	30,824	21	8,697	30	2,017	13	1,589
			384	288	110,840	62,019	767	45,077	30	9,268	190	4,869	37	2,805
	Total power		1,853	155	289,867	184,965	1,841	136,549	129	40,742	190	4,869	37	2,805
	Grand total		2,937	.....	289,867	184,965	1,841	136,549	129	40,742	190	4,869	37	2,805
9a. Cement.	No power		1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	Steam power only:													
		201-500	1	400	400	400	0	0	0	400	.....	.....	.....	.....
		501 and above	8	7,090	56,750	56,750	113	54,000	2	2,750	.....	.....	.....	.....
			9	6,350	57,150	57,150	113	54,000	4	3,150	.....	.....	.....	.....
	Purchased electric power only:													
		1-200	3	72	216	.....	.....	.....	.....	.....	.....	.....	.....	.....
		501 and above	8	4,141	33,127	.....	.....	.....	.....	.....	.....	.....	.....	.....
			11	3,031	33,343	.....	.....	.....	.....	.....	.....	.....	.....	.....
	All other power:													
		501 and above	8	8,947	71,573	57,736	79	40,694	9	10,920	15	6,072	1	50
	Total power		28	5,800	162,066	114,886	192	94,694	13	14,070	15	6,072	1	50
	Grand total		29	.....	162,066	114,886	192	94,694	13	14,070	15	6,072	1	50
9b. All other stone products.	No power		467	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	Steam power only:													
		1-200	120	74	8,796	8,796	198	8,781	1	15	.....	.....	.....	.....
		201-500	23	303	6,951	6,951	76	6,801	1	150	.....	.....	.....	.....
		501 and above	6	690	4,130	4,130	46	3,980	1	150	.....	.....	.....	.....
			149	132	19,877	19,877	320	19,562	3	315	.....	.....	.....	.....
	Purchased electric power only:													
		1-200	648	20	12,733	.....	.....	.....	.....	.....	.....	.....	.....	.....
		201-500	9	330	2,973	.....	.....	.....	.....	.....	.....	.....	.....	.....
		501 and above	4	1,212	4,847	.....	.....	.....	.....	.....	.....	.....	.....	.....
			661	31	20,553	.....	.....	.....	.....	.....	.....	.....	.....	.....
	All other power:													
		1-200	407	29	11,726	8,450	112	4,602	0	0	355	3,746	5	102
		201-500	28	301	8,438	4,902	74	4,328	0	0	46	354	1	220
		501 and above	12	1,310	15,710	8,122	183	6,453	2	1,667	1	2	0	0
			447	80	35,814	21,474	369	15,383	2	1,667	402	4,102	6	322
	Total power		1,257	60	76,304	41,351	689	34,945	5	1,982	402	4,102	6	322
	Grand total		1,724	.....	76,304	41,351	689	34,945	5	1,982	402	4,102	6	322

by industry subgroups, by character of power supply—Continued.

Power-supply equipment—Continued.				Electric motors.				Fuel used.			
Operated by purchased energy.				Total.		Run by current generated in establishment.		Coal.			
Total horsepower.	Electric motors.		Other (horsepower).					Anthracite (long tons).	Bituminous (short tons).	Total equivalent bituminous (short tons).	Coke (short tons).
	Number.	Horsepower.		Number.	Horsepower.	Number.	Horsepower.				
16	17	18	19	20	21	22	23	24	25	26	27
.....	.....	.....	.....	.....	.....	.....	.....	17,747	38,978	54,953	327
.....	.....	.....	.....	466	4,867	466	4,867	88,393	186,889	266,443	6,072
.....	.....	.....	.....	1,192	12,562	1,192	12,562	60,491	190,625	245,066	5,364
.....	.....	.....	.....	5,309	63,872	5,309	63,872	304,617	736,776	1,010,933	10,509
.....	.....	.....	.....	6,967	81,301	6,967	81,301	453,501	1,114,290	1,522,442	21,945
20,788	3,459	20,788	.....	3,459	20,788	.....	.....	123,834	87,017	198,468	3,597
12,805	1,083	12,805	.....	1,083	12,805	.....	.....	9,016	47,344	55,458	1,648
22,488	1,172	22,488	.....	1,172	22,488	.....	.....	14,180	86,066	98,828	180
56,081	5,714	56,081	.....	5,714	56,081	.....	.....	147,030	220,427	352,754	5,425
5,480	779	4,869	611	914	5,636	135	767	53,270	69,402	117,345	2,595
6,035	580	6,035	0	841	8,577	261	2,542	71,528	67,974	132,351	3,593
37,306	2,455	37,306	0	3,510	49,691	1,055	12,385	250,121	445,742	670,850	5,955
48,821	3,814	48,210	611	5,265	63,904	1,451	15,694	374,919	583,118	920,546	12,143
104,902	9,528	104,291	611	17,946	201,286	8,418	96,995	975,450	1,917,835	2,795,742	39,513
104,902	9,528	104,291	611	17,946	201,286	8,418	96,995	993,197	1,956,813	2,850,695	39,840
.....	.....	.....	.....	.....	.....	.....	.....	42	128	165	0
.....	.....	.....	.....	25	500	25	500	0	7,436	7,436	0
.....	.....	.....	.....	836	26,271	836	26,271	214,422	810,711	1,003,711	0
.....	.....	.....	.....	861	26,771	861	26,771	214,422	818,147	1,011,147	00
216	16	216	.....	16	216	.....	.....	0	0	0	120
33,127	610	33,127	.....	610	33,127	.....	.....	7,370	285,379	292,009	1,466
33,343	626	33,343	.....	626	33,343	.....	.....	7,370	285,379	292,009	1,586
13,837	211	13,837	0	499	28,128	288	14,291	50,407	750,867	796,167	0
47,180	837	47,180	0	1,986	88,242	1,149	41,062	272,199	1,854,393	2,099,323	1,586
47,180	837	47,180	0	1,986	88,242	1,149	41,062	272,241	1,854,521	2,099,488	1,586
.....	.....	.....	.....	.....	.....	.....	.....	7,510	17,361	24,111	2,065
.....	.....	.....	.....	36	500	36	500	16,758	27,468	42,468	3,861
.....	.....	.....	.....	146	1,845	146	1,845	18,648	21,277	37,977	0
.....	.....	.....	.....	48	1,653	48	1,653	7,865	22,885	29,935	30,900
.....	.....	.....	.....	230	3,998	230	3,998	43,271	71,630	110,380	34,761
12,733	1,157	12,733	.....	1,157	12,733	.....	.....	5,388	13,311	18,141	3,921
2,973	209	2,973	.....	209	2,973	.....	.....	1,400	25,100	26,360	0
4,847	190	4,847	.....	190	4,847	.....	.....	215	21,599	21,792	0
20,553	1,556	20,553	.....	1,556	20,553	.....	.....	7,003	60,010	66,293	3,921
3,276	219	2,937	339	249	2,357	30	320	13,133	33,830	45,630	3,259
3,536	172	3,536	0	203	3,984	31	448	3,511	35,937	39,097	50
7,588	369	7,588	0	429	8,938	60	1,350	21,758	65,141	84,641	9,382
14,400	760	14,061	339	881	16,179	121	2,118	38,402	134,908	169,368	12,691
34,953	2,316	34,614	339	2,667	40,730	351	6,116	88,676	266,548	346,041	51,373
34,953	2,316	34,614	339	2,667	40,730	351	6,116	96,186	283,909	370,152	53,438

TABLE 46.—*Mechanical power-supply equipment and fuel used*

Industry subgroup.	Character of power supply.	Size of plant (horsepower).	Establishments.		Power-supply equipment.									
						Prime movers.								
							Steam engines.		Steam turbines.		Internal-combustion engines.		Water wheels.	
			Number.	Average size (horsepower).	Aggregate horsepower.	Total horsepower.	Number.	Horsepower.	Number.	Horsepower.	Number.	Horsepower.	Number.	Horsepower.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
9c. All clay products.	No power		101											
	Steam power only:													
		1-200	192	84	16,158	16,156	242	16,078	2	80				
		201-500	41	329	13,476	13,476	109	13,476	0	0				
		501 and above	15	882	13,250	13,250	66	12,500	1	750				
			248	180	42,884	42,884	417	42,054	3	830				
	Purchased electric power only:													
		1-200	160	52	8,315									
		201-500	25	233	5,826									
		501 and above	3	860	2,580									
			188	89	16,721									
	All other power:													
		1-200	95	87	8,256	6,464	67	4,475	0	0	53	1,034	18	955
		201-500	46	298	13,712	10,472	97	8,117	2	295	22	633	13	1,427
		501 and above	16	750	12,029	7,472	65	6,904	0	0	13	238	2	330
			157	216	33,997	24,408	229	19,496	2	295	88	1,905	33	2,712
	Total power		593	168	93,602	67,292	646	61,550	5	1,125	88	1,905	33	2,712
	Grand total		694		93,602	67,292	646	61,550	5	1,125	88	1,905	33	2,712
9d. All glass products.	No power		109											
	Steam power only:													
		1-200	27	66	1,766	1,766	31	1,566	2	200				
		201-500	2	305	610	610	7	610	0	0				
		501 and above	1	885	885	885	17	885	0	0				
			30	109	3,261	3,261	55	3,061	2	200				
	Purchased electric power only:													
		1-200	232	9	2,191									
		201-500	5	352	1,760									
		501 and above	2	632	1,263									
			239	22	5,214									
	All other power:													
		1-200	51	36	1,831	1,096	16	429	0	0	33	627	2	40
		201-500	4	248	993	220	4	220	0	0	0	0	0	0
		501 and above	2	874	1,747	1,245	2	45	0	0	3	1,200	0	0
			57	80	4,571	2,561	22	694	0	0	36	1,827	2	40
	Total power		326	40	13,046	5,822	77	3,755	2	200	36	1,827	2	40
	Grand total		435		13,046	5,822	77	3,755	2	200	36	1,827	2	40
10a. Metals other than iron and steel.	No power		90											
	Steam power only:													
		1-200	33	65	2,143	2,143	38	2,143	0	0				
		201-500	6	327	1,963	1,963	11	1,963	0	0				
		501 and above	14	10,300	144,708	144,708	117	62,630	60	82,078				
			53	2,800	148,814	148,814	166	66,736	60	82,078				
	Purchased electric power only:													
		1-200	372	24	8,884									
		201-500	15	310	4,654									
		501 and above	11	2,103	23,136									
			398	92	36,674									
	All other power:													
		1-200	119	24	2,854	1,655	6	305	1	10	84	1,310	3	30
		201-500	11	348	3,831	2,165	11	1,405	0	0	3	500	5	260
		501 and above	25	4,201	105,036	43,192	103	29,245	10	11,267	4	650	13	2,030
			155	720	111,721	47,012	120	30,955	11	11,277	91	2,460	21	2,320
	Total power		606	490	297,209	195,826	286	97,691	71	93,355	91	2,460	21	2,320
	Grand total		696		297,209	195,826	286	97,691	71	93,355	91	2,460	21	2,320

by industry subgroups, by character of power supply—Continued.

Power-supply equipment—Continued.				Electric motors.				Fuel used.			
Operated by purchased energy.											
Total horsepower.	Electric motors.		Other (horsepower).	Total.		Run by current generated in establishment.		Coal.			Coke (short tons).
	Number.	Horsepower.		Number.	Horsepower.	Number.	Horsepower.	Anthracite (long tons).	Bituminous (short tons).	Total equivalent bituminous (short tons).	
16	17	18	19	20	21	22	23	24	25	26	27
.....	.....	.....	.....	.....	.....	.....	.....	3,879	12,493	16,003	144
.....	.....	.....	.....	60	506	60	506	40,566	174,129	210,652	940
.....	.....	.....	.....	140	2,167	140	2,167	19,724	94,358	112,109	1,049
.....	.....	.....	.....	144	3,992	144	3,992	38,424	64,395	98,973	138
.....	.....	.....	.....	344	6,665	344	6,665	98,714	332,882	421,734	2,127
8,315	537	8,315	.....	537	8,315	.....	.....	13,094	57,225	69,010	349
5,826	131	5,826	.....	131	5,826	.....	.....	2,818	44,588	46,408	372
2,580	86	2,580	.....	86	2,580	.....	.....	45	19,228	19,268	340
16,721	754	16,721	.....	754	16,721	.....	.....	15,957	121,041	134,686	1,061
1,792	153	1,745	47	153	1,745	0	0	24,121	46,063	67,771	2,171
3,240	167	3,240	0	204	3,865	37	625	11,553	102,304	112,699	750
4,557	198	4,557	0	273	5,049	75	492	22,068	123,455	143,316	369
9,589	518	9,542	47	630	10,659	112	1,117	57,742	271,822	323,786	3,290
26,310	1,272	26,263	47	1,728	34,045	456	7,782	172,413	725,745	880,206	6,478
26,310	1,272	26,263	47	1,728	34,045	456	7,782	176,312	738,238	896,209	6,622
.....	.....	.....	.....	.....	.....	.....	.....	231	55	262	125
.....	.....	.....	.....	39	239	39	239	5,396	46,479	51,329	889
.....	.....	.....	.....	44	392	44	392	0	17,111	17,111	0
.....	.....	.....	.....	25	168	25	168	239	37,768	37,398	0
.....	.....	.....	.....	108	799	108	799	5,635	101,358	106,423	889
2,191	576	2,191	.....	576	2,191	.....	.....	2,951	13,143	15,793	285
1,760	138	1,760	.....	138	1,760	.....	.....	.....	36,951	36,951	0
1,263	31	1,263	.....	31	1,263	.....	.....	40	4,732	4,769	0
5,214	745	5,214	.....	745	5,214	.....	.....	2,991	54,826	57,513	285
735	95	639	96	111	765	16	126	3,091	26,223	29,003	5,092
773	43	773	0	43	773	0	0	297	5,864	6,131	200
502	39	502	0	130	1,966	91	1,464	0	42,847	42,847	0
2,010	177	1,914	96	284	3,504	107	1,590	3,388	74,934	77,981	5,292
7,224	922	7,128	96	1,137	9,517	215	2,389	12,014	231,118	241,917	6,466
7,224	922	7,128	96	1,137	9,517	215	2,389	12,245	231,173	242,179	6,591
.....	.....	.....	.....	.....	.....	.....	.....	2,737	2,892	5,252	944
.....	.....	.....	.....	63	764	63	764	6,157	9,149	14,649	1,764
.....	.....	.....	.....	55	993	55	993	773	10,137	10,832	2,880
.....	.....	.....	.....	3,685	66,628	3,685	66,628	621,618	613,713	1,173,713	155,913
.....	.....	.....	.....	3,803	68,385	3,803	68,385	628,548	632,999	1,199,194	160,557
8,884	1,287	8,884	.....	1,287	8,884	.....	.....	21,164	20,008	39,008	117,034
4,654	631	4,654	.....	631	4,654	.....	.....	1,848	5,034	6,694	1,790
23,136	1,003	23,136	.....	1,003	23,136	.....	.....	27,009	12,271	56,571	1,253
36,674	2,921	36,674	.....	2,921	36,674	.....	.....	50,021	37,313	82,273	120,077
1,199	81	761	438	83	762	2	1	4,725	10,115	14,365	5,061
1,666	133	1,666	0	165	2,002	32	336	2,036	15,289	17,129	5,627
61,844	2,412	48,159	13,685	2,944	62,640	532	14,481	108,408	281,089	378,589	37,129
64,709	2,626	50,586	14,123	3,192	65,404	566	14,818	115,169	306,493	410,083	47,817
101,383	5,547	87,260	14,123	9,916	170,463	4,369	83,203	793,738	976,805	1,691,550	328,451
101,383	5,547	87,260	14,123	9,916	170,463	4,369	83,203	796,475	979,697	1,696,803	329,395

TABLE 46.—*Mechanical power-supply equipment and fuel used*

Industry subgroup.	Character of power supply.	Size of plant (horsepower).	Establishments.		Power-supply equipment.									
						Prime movers.								
			Number.	Average size (horsepower).	Aggregate horsepower.	Total horsepower.	Steam engines.		Steam turbines.		Internal-combustion engines.		Water wheels.	
							Number.	Horsepower.	Number.	Horsepower.	Number.	Horsepower.	Number.	Horsepower.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
10b. Metal products other than iron and steel.	No power		1,174											
	Steam power only:													
		1-200	68	77	5,235	5,235	75	5,160	1	75				
		201-500	16	296	4,769	4,769	27	3,941	8	828				
		501 and above	8	774	6,196	6,196	29	6,196	0	0				
			92	176	16,200	16,200	131	15,297	9	903				
	Purchased electric power only:													
		1-200	2,163	12	26,618									
		201-500	22	272	5,992									
		501 and above	8	830	6,639									
			2,193	18	39,249									
	All other power:													
		1-200	485	27	13,223	8,442	62	4,207	4	225	194	3,399	20	611
		201-500	20	296	5,925	3,695	29	2,733	0	0	1	55	13	907
		501 and above	27	1,240	33,443	21,611	63	16,338	4	3,098	5	1,020	18	1,155
			532	99	52,591	33,748	154	23,278	8	3,323	200	4,474	51	2,673
	Total power		2,817	383	108,040	49,948	285	38,575	17	4,226	200	4,474	51	2,673
	Grand total		3,991		108,040	49,948	285	38,575	17	4,226	200	4,474	51	2,673
11. Tobacco manufactures.	No power		3,608											
	Steam power only:													
		1-200	32	67	2,135	2,135	41	2,135	0	0				
		201-500	3	222	666	666	9	666	0	0				
		501 and above	2	940	1,880	1,880	7	1,880	0	0				
			37	127	4,681	4,681	57	4,681	0	0				
	Purchased electric power only:													
		1-200	480	8	3,638									
		201-500	3	387	1,162									
			483	10	4,800									
	All other power:													
		1-200	39	56	2,169	1,744	24	1,368	1	40	17	176	3	160
		201-500	5	279	1,396	645	7	545	0	0	0	0	4	100
		501 and above	3	763	2,288	1,703	19	1,150	1	536	0	0	1	17
			47	124	5,853	4,092	50	3,063	2	576	17	176	8	277
	Total power		567	27	15,334	8,773	107	7,744	2	576	17	176	8	277
	Grand total		4,175		15,334	8,773	107	7,744	2	576	17	176	8	277
12a. Automobiles.	No power		257											
	Steam power only:													
		1-200	25	46	1,115	1,115	21	1,115	0	0				
		201-500	4	338	1,350	1,350	8	1,200	1	150				
		501 and above	5	1,375	6,875	6,875	11	3,375	3	3,500				
			34	273	9,340	9,340	40	5,690	4	3,650				
	Purchased electric power only:													
		1-200	2,770	7	19,899									
		201-500	12	331	3,966									
		501 and above	8	1,624	12,993									
			2,790	13	36,858									
	All other power:													
		1-200	378	11	4,264	3,629	24	1,065	0	0	365	2,368	4	196
		201-500	5	281	1,407	855	6	615	0	0	2	240	0	0
		501 and above	7	919	6,438	2,270	12	1,880	2	225	1	165	0	0
			390	31	12,109	6,754	42	3,560	2	225	368	2,773	4	196
	Total power		3,214	18	58,307	16,094	82	9,250	6	3,875	368	2,773	4	196
	Grand total		3,471		58,307	16,094	82	9,250	6	3,875	368	2,773	4	196

by industry subgroups, by character of power supply—Continued.

Power-supply equipment—Continued.				Electric motors.				Fuel used.			
Operated by purchased energy.				Total.		Run by current generated in establishment.		Coal.			Coke (short tons).
Total horsepower.	Electric motors.		Other (horsepower).					Anthracite (long tons).	Bituminous (short tons).	Total equivalent bituminous (short tons).	
	Number.	Horsepower.		Number.	Horsepower.	Number.	Horse power.				
16	17	18	19	20	21	22	23	24	25	26	27
.....	.....	.....	.....	.....	.....	.....	.....	2,350	899	3,014	817
.....	.....	.....	.....	317	2,039	317	2,039	11,370	21,267	31,500	2,094
.....	.....	.....	.....	577	2,954	577	2,954	8,956	15,257	23,322	43
.....	.....	.....	.....	577	7,958	577	7,958	14,737	29,630	42,896	734
.....	.....	.....	.....	1,471	12,951	1,471	12,951	35,063	66,154	97,718	2,871
26,618	7,384	26,618	.....	7,384	26,618	.....	.....	13,100	15,314	27,104	3,564
5,992	617	5,992	.....	617	5,992	.....	.....	388	6,726	7,075	192
6,639	613	6,639	.....	613	6,639	.....	.....	1,978	5,428	7,210	0
39,249	8,614	39,249	.....	8,614	39,249	.....	.....	15,466	27,468	41,389	3,756
4,781	350	2,567	2,214	900	4,901	550	2,334	5,510	30,135	35,094	1,627
2,230	291	1,980	250	485	3,543	194	1,563	3,848	17,727	21,195	0
11,832	1,908	11,832	0	3,307	22,640	1,399	10,808	25,149	84,421	107,156	766
18,843	2,549	16,379	2,464	4,692	31,084	2,143	14,705	34,507	132,283	163,445	2,393
58,092	11,163	55,628	2,464	14,777	83,284	3,614	27,656	85,036	225,905	302,552	9,020
58,092	11,163	55,628	2,464	14,777	83,284	3,614	27,656	87,386	226,804	305,566	9,837
.....	.....	.....	.....	.....	.....	.....	.....	8,198	2,513	9,863	10
.....	.....	.....	.....	107	598	107	598	5,914	4,373	9,693	58
.....	.....	.....	.....	9	240	9	240	890	4,652	5,442	0
.....	.....	.....	.....	99	1,386	99	1,386	46	13,996	14,037	180
.....	.....	.....	.....	215	2,224	215	2,224	6,850	23,021	29,172	238
3,638	1,274	3,638	.....	1,274	3,638	.....	.....	11,206	4,878	14,978	482
1,162	74	1,162	.....	74	1,162	.....	.....	299	400	668	0
4,800	1,348	4,800	.....	1,348	4,800	.....	.....	11,505	5,278	15,646	482
425	94	425	0	155	872	61	447	6,073	2,927	8,477	0
751	263	751	0	294	999	31	248	2,212	1,235	3,225	0
585	40	585	0	40	585	0	0	4,691	5,033	9,233	178
1,761	397	1,761	0	489	2,456	92	695	12,976	9,195	20,935	178
6,561	1,745	6,561	0	2,052	9,480	307	2,919	31,331	37,494	65,753	898
6,561	1,745	6,561	0	2,052	9,480	307	2,919	39,529	40,007	75,616	908
.....	.....	.....	.....	.....	.....	.....	.....	1,291	384	1,549	0
.....	.....	.....	.....	79	489	79	489	1,561	8,199	9,603	0
.....	.....	.....	.....	16	121	16	121	2,113	3,996	5,900	0
.....	.....	.....	.....	348	4,590	348	4,590	3,659	27,690	30,983	0
.....	.....	.....	.....	443	5,200	443	5,200	7,333	39,885	46,486	0
19,899	5,645	19,899	.....	5,645	19,899	.....	.....	26,771	23,937	48,030	488
3,966	449	3,966	.....	449	3,966	.....	.....	3,418	3,098	6,175	2
12,993	1,746	12,993	.....	1,746	12,993	.....	.....	14,772	24,940	38,233	580
36,858	7,840	36,858	.....	7,840	36,858	.....	.....	44,961	51,975	92,438	1,070
635	162	554	81	202	754	40	200	3,065	4,761	7,520	91
552	84	552	0	91	588	7	36	850	3,095	3,860	50
4,168	367	4,168	0	490	5,016	123	848	902	18,425	19,237	2
5,355	613	5,274	81	783	6,358	170	1,084	4,817	26,281	30,617	143
42,213	8,453	42,132	81	9,066	48,416	613	6,284	57,111	118,141	169,541	1,213
42,213	8,453	42,132	81	9,066	48,416	613	6,284	58,402	118,525	171,090	1,213

TABLE 46.—*Mechanical power-supply equipment and fuel used*

Industry subgroup.	Character of power supply.	Size of plant (horsepower).	Establishments.		Power-supply equipment.										
						Prime movers.									
			Number.	Average size (horsepower).	Aggregate horsepower.	Total horsepower.	Steam engines.		Steam turbines.		Internal-combustion engines.		Water wheels.	
							Number.	Horsepower.	Number.	Horsepower.	Number.	Horsepower.	Number.	Horsepower.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
12b. Cars not by railroads.	Steam power only:													
		1-200	2	110	220	220	3	220	0	0	.....	.....	.....	.....
		201-500	1	350	350	350	2	350	0	0	.....	.....	.....	.....
			3	190	570	570	5	570	0	0	.....	.....	.....	.....
	Purchased electric power only:													
		501 and above	2	2,772	5,543	.....	.....	.....	.....	.....	.....	.....	.....	.....
	All other power:													
		501 and above	6	2,752	16,515	4,828	14	4,320	1	500	2	8	0	0
	Total power		11	2,057	22,628	5,398	19	4,890	1	500	2	8	0	0
	No power		186	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
12c. All other vehicles.	Steam power only:													
		1-200	30	48	1,431	1,431	27	1,375	2	56	.....	.....	.....	.....
		201-500	1	300	300	300	1	300	0	0	.....	.....	.....	.....
			31	56	1,731	1,731	28	1,675	2	56	.....	.....	.....	.....
	Purchased electric power only:													
		1-200	450	8	3,618	.....	.....	.....	.....	.....	.....	.....	.....	.....
		201-500	1	395	395	.....	.....	.....	.....	.....	.....	.....	.....	.....
		501 and above	1	2,074	2,074	.....	.....	.....	.....	.....	.....	.....	.....	.....
			452	13	6,087	.....	.....	.....	.....	.....	.....	.....	.....	.....
	All other power:													
		1-200	148	20	3,017	2,509	16	795	0	0	128	1,083	18	631
		201-500	4	348	1,390	1,200	5	775	0	0	0	0	9	515
		501 and above	2	1,110	2,220	1,200	4	1,200	0	0	0	0	0	0
			154	43	6,627	4,999	25	2,770	0	0	128	1,083	27	1,146
	Total power		637	23	14,445	6,730	53	4,445	2	56	128	1,083	27	1,146
	Grand total		823	.....	14,445	6,730	53	4,445	2	56	128	1,083	27	1,146
13a. Steam railroad repair shops.	No power		26	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	Steam power only:													
		1-200	40	62	2,496	2,496	56	2,446	1	50	.....	.....	.....	.....
		201-500	12	293	3,521	3,521	33	3,521	0	0	.....	.....	.....	.....
		501 and above	25	1,960	49,006	49,006	182	43,456	10	5,550	.....	.....	.....	.....
			77	715	55,023	55,023	271	49,423	11	5,600	.....	.....	.....	.....
	Purchased electric power only:													
		1-200	50	59	2,974	.....	.....	.....	.....	.....	.....	.....	.....	.....
		201-500	8	259	2,075	.....	.....	.....	.....	.....	.....	.....	.....	.....
		501 and above	7	1,034	7,238	.....	.....	.....	.....	.....	.....	.....	.....	.....
			65	189	12,287	.....	.....	.....	.....	.....	.....	.....	.....	.....
	All other power:													
		1-200	27	102	2,748	1,728	26	1,521	0	0	16	207	0	0
		201-500	5	383	1,915	660	7	660	0	0	0	0	0	0
		501 and above	15	1,880	28,371	10,333	62	9,537	3	550	6	151	2	95
			47	702	33,034	12,721	95	11,718	3	550	22	358	2	95
	Total power		189	530	100,344	67,744	366	61,141	14	6,150	22	358	2	95
	Grand total		215	.....	100,344	67,744	366	61,141	14	6,150	22	358	2	95

by industry subgroups, by character of power supply—Continued.

Power-supply equipment—Continued.				Electric motors.				Fuel used.			
Operated by purchased energy.				Total.		Run by current generated in establishment.		Coal.			Coke (short tons).
Total horsepower.	Electric motors.		Other (horsepower).					Anthracite (long tons).	Bituminous (short tons).	Total equivalent bituminous (short tons).	
	Number.	Horsepower.		Number.	Horsepower.	Number.	Horse power.				
16	17	18	19	20	21	22	23	24	25	26	27
.....	.....	.....	.....	50	200	50	200	384	700	1,044	0
.....	.....	.....	.....	15	231	15	231	3	5,574	5,574	30
.....	.....	.....	.....	65	431	65	431	387	6,274	6,618	30
5,543	340	5,543	.....	340	5,543	.....	.....	232	7,838	8,046	282
11,687	689	11,687	0	1,593	20,792	904	9,105	37,852	68,816	102,816	8,432
17,230	1,029	17,230	0	1,998	26,766	969	9,536	38,471	82,928	117,480	8,744
.....	.....	.....	.....	.....	.....	.....	.....	304	1,129	1,403	11
.....	.....	.....	.....	7	148	7	148	2,134	4,328	6,238	428
.....	.....	.....	.....	0	0	0	0	0	991	991	0
.....	.....	.....	.....	7	148	7	148	2,134	5,319	7,229	428
3,618	1,083	3,618	.....	1,083	3,618	.....	.....	2,486	5,531	7,771	41
395	27	395	.....	27	395	.....	.....	5	1,400	1,405	0
2,074	130	2,074	.....	130	2,074	.....	.....	4,280	2,392	6,242	0
6,087	1,240	6,087	.....	1,240	6,087	.....	.....	6,771	9,323	15,418	41
508	98	425	83	127	627	29	202	1,227	4,996	6,096	67
100	3	100	0	4	101	1	1	0	1,604	1,604	75
1,020	69	1,020	0	77	1,280	8	260	360	4,461	4,785	0
1,628	170	1,545	83	208	2,008	38	463	1,587	11,061	12,485	142
7,715	1,410	7,632	83	1,455	8,243	45	611	10,492	25,703	35,132	611
7,715	1,410	7,632	83	1,455	8,243	45	611	10,795	26,832	36,535	622
.....	.....	.....	.....	.....	.....	.....	.....	737	4,115	4,778	0
.....	.....	.....	.....	65	1,442	65	1,442	17,838	57,310	73,360	0
.....	.....	.....	.....	182	3,932	182	3,932	38,690	43,623	78,444	0
.....	.....	.....	.....	3,013	41,309	3,013	41,309	245,406	226,354	447,220	202,313
.....	.....	.....	.....	3,260	46,683	3,260	46,683	301,934	327,287	599,024	202,313
2,974	240	2,974	.....	240	2,974	.....	.....	3,240	46,311	49,227	9
2,075	106	2,075	.....	106	2,075	.....	.....	2,056	5,018	6,870	0
7,238	268	7,238	.....	268	7,238	.....	.....	14,534	65,035	78,116	294
12,287	614	12,287	.....	614	12,287	.....	.....	19,830	116,364	134,213	303
1,020	50	670	350	59	815	3	145	11,986	44,300	55,088	0
1,255	51	1,005	250	51	1,005	0	0	1,321	4,853	6,042	253
18,038	962	18,038	0	1,059	20,056	97	2,018	85,897	103,024	180,332	2,216
20,313	1,069	19,713	600	1,169	21,876	100	2,163	99,204	152,177	241,462	2,469
32,600	1,683	32,000	600	5,043	80,846	3,360	48,846	420,968	595,828	974,699	205,085
32,600	1,683	32,000	600	5,043	80,846	3,360	48,846	421,705	599,943	979,477	205,085

TABLE 46.—*Mechanical power-supply equipment and fuel used*

Industry subgroup.	Character of power supply.	Size of plant (horsepower).	Establishments.		Power-supply equipment.									
						Prime movers.								
							Steam engines.		Steam turbines.		Internal-combustion engines.		Water wheels.	
			Number.	Average size (horsepower).	Aggregate horsepower.	Total horsepower.	Number.	Horsepower.	Number.	Horsepower.	Number.	Horsepower.	Number.	Horsepower.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
13b. Electric railroad repair shops.	No power		27											
	Steam power only:													
		1-200	7	41	285	285	13	285	0	0				
		201-500	1	400	400	400	2	400	0	0				
			8	86	685	685	15	685	0	0				
	Purchased electric power only:													
		1-200	101	94	9,485									
		201-500	11	360	3,954									
		501 and above	4	1,171	4,683									
			116	156	18,122									
	All other power:													
		1-200	2	65	130	100	1	100	0	0	0	0	0	0
		501 and above	1	625	625	20	2	20	0	0	0	0	0	0
			3	252	755	120	3	120	0	0	0	0	0	0
	Total power		127	153	19,562	805	18	805	0	0	0	0	0	0
	Grand total		154		19,562	805	18	805	0	0	0	0	0	0
14a. Miscellaneous metal products.	No power		56											
	Steam power only:													
		1-200	23	84	1,942	1,942	26	1,942	0	0				
		201-500	6	304	1,825	1,825	9	1,825	0	0				
		501 and above	3	2,373	7,121	7,121	5	1,100	5	6,021				
			32	34	10,888	10,888	40	4,867	5	6,021				
	Purchased electric power only:													
		1-200	393	15	5,958									
		201-500	6	285	1,712									
		501 and above	4	1,378	5,510									
			403	33	13,180									
	All other power:													
		1-200	73	41	2,995	2,293	12	734	0	0	48	664	19	895
		201-500	7	295	2,068	1,240	11	605	0	0	4	475	2	160
		501 and above	9	3,517	31,652	19,334	50	6,212	24	10,382	10	2,093	3	647
			89	412	36,715	22,867	73	7,551	24	10,382	62	3,232	24	1,702
	Total power		524	116	60,783	33,755	113	12,418	29	16,403	62	3,232	24	1,702
	Grand total		580		60,783	33,755	113	12,418	29	16,403	62	3,232	24	1,702
14b. Rubber goods.	No power		7											
	Steam power only:													
		1-200	15	127	1,915	1,915	19	1,915	0	0				
		201-500	17	321	5,788	5,788	35	5,788	0	0				
		501 and above	20	1,606	32,127	32,127	55	20,803	12	11,324				
			52	765	39,830	39,830	109	28,506	12	11,324				
	Purchased electric power only:													
		1-200	55	42	2,333									
		201-500	11	316	3,482									
		501 and above	11	2,553	28,089									
			77	440	33,904									
	All other power:													
		1-200	19	105	2,008	1,215	12	800	0	0	3	200	2	215
		201-500	20	313	6,257	4,331	28	3,870	0	0	1	6	6	455
		501 and above	49	1,890	93,121	42,691	124	36,369	15	2,740	3	817	20	2,765
			88	1,140	101,386	48,237	164	41,039	15	2,740	7	1,023	28	3,435
	Total power		217	1,500	175,120	88,067	273	69,545	27	14,064	7	1,023	28	3,435
	Grand total		224		175,120	88,067	273	69,545	27	14,064	7	1,023	28	3,435

by industry subgroups, by character of power supply—Continued.

Power-supply equipment—Continued.				Electric motors.				Fuel used.			
Operated by purchased energy.				Total.		Run by current generated in establishment.		Coal.			Coke (short tons).
Total horsepower.	Electric motors.		Other (horsepower).					Anthracite (long tons).	Bituminous (short tons).	Total equivalent bituminous (short tons).	
	Number.	Horsepower.		Number.	Horsepower.	Number.	Horsepower.				
16	17	18	19	20	21	22	23	24	25	26	27
.....	.....	.....	.....	.....	.....	.....	.....	782	304	1,006	1
.....	.....	.....	.....	0	0	0	0	30	581	608	0
.....	.....	.....	.....	0	0	0	0	0	4,397	4,397	0
.....	.....	.....	.....	0	0	0	0	30	4,978	5,005	0
9,485	584	9,485	.....	584	9,485	.....	.....	6,040	9,641	15,071	0
3,954	219	3,954	.....	219	3,954	.....	.....	1,896	1,564	3,264	0
4,683	256	4,683	.....	256	4,683	.....	.....	5,393	530	5,380	0
18,122	1,059	18,122	.....	1,059	18,122	.....	.....	13,329	11,735	23,715	0
30	1	5	25	1	5	0	0	20	0	18	0
605	20	605	0	20	605	0	0	0	13,422	13,422	0
635	21	610	25	21	610	0	0	20	13,422	13,440	0
18,757	1,080	18,732	25	1,080	18,732	0	0	13,379	30,135	42,160	0
18,757	1,080	18,732	25	1,080	18,732	0	0	14,161	30,439	43,166	1
.....	.....	.....	.....	.....	.....	.....	.....	190	199	370	0
.....	.....	.....	.....	212	545	212	545	3,019	4,969	7,687	711
.....	.....	.....	.....	66	364	66	364	2,732	1,693	4,180	0
.....	.....	.....	.....	378	1,560	378	1,560	3,716	24,200	27,548	0
.....	.....	.....	.....	656	2,469	656	2,469	9,467	30,062	39,415	711
5,958	1,841	5,958	.....	1,841	5,958	.....	.....	6,461	6,835	12,649	133
1,712	166	1,712	.....	166	1,712	.....	.....	968	3,197	4,070	0
5,510	502	5,510	.....	502	5,510	.....	.....	80	9,084	9,156	0
13,180	2,509	13,180	.....	2,509	13,180	.....	.....	7,509	19,116	25,875	133
702	102	561	141	158	794	56	233	3,813	1,461	4,890	548
828	126	828	0	127	883	1	55	27,090	2,975	27,356	3,408
12,318	1,039	12,318	0	2,593	26,015	1,554	13,697	16,901	102,782	117,990	4,420
13,848	1,267	13,707	141	2,878	27,692	1,611	13,985	47,804	107,218	150,236	8,376
27,028	3,776	26,887	141	6,043	43,341	2,267	16,454	64,780	157,196	215,526	9,220
27,028	3,776	26,887	141	6,043	43,341	2,267	16,454	64,970	157,395	215,896	9,220
.....	.....	.....	.....	.....	.....	.....	.....	115	1,100	1,203	0
.....	.....	.....	.....	13	125	13	125	1,434	10,745	12,035	0
.....	.....	.....	.....	112	2,314	112	2,314	9,737	22,174	30,924	70
.....	.....	.....	.....	1,288	23,582	1,288	23,582	46,190	151,602	193,202	3,099
.....	.....	.....	.....	1,413	26,021	1,413	26,021	57,361	184,521	236,161	3,169
2,333	178	2,333	.....	178	2,333	.....	.....	471	4,544	4,969	0
3,482	108	3,482	.....	108	3,482	.....	.....	809	15,573	16,300	0
28,089	1,412	28,089	.....	1,412	28,089	.....	.....	4,121	58,335	62,055	0
33,904	1,698	33,904	.....	1,698	33,904	.....	.....	5,401	78,452	83,324	0
793	58	666	127	58	666	0	0	2,190	5,309	7,279	0
1,926	106	1,926	0	124	2,123	18	197	1,857	26,769	28,429	825
50,430	2,101	50,430	0	3,073	60,944	972	10,514	61,377	289,312	344,512	12
53,149	2,265	53,022	127	3,255	63,733	990	10,711	65,424	321,390	380,220	837
87,053	3,963	86,926	127	6,366	123,658	2,403	36,732	128,186	584,363	699,705	4,006
87,053	3,963	86,926	127	6,366	123,658	2,403	36,732	128,301	585,463	700,908	4,006

TABLE 46.—*Mechanical power-supply equipment and fuel used*

Industry subgroup.	Character of power supply.	Size of plant (horsepower).	Establishments.		Power-supply equipment.									
						Prime movers.								
			Number.	Average size (horsepower).	Aggregate horsepower.	Total horsepower.	Steam engines.		Steam turbines.		Internal-combustion engines.		Water wheels.	
							Number.	Horsepower.	Number.	Horsepower.	Number.	Horsepower.	Number.	Horsepower.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
14c. Electrical machinery.	No power		30											
	Steam power only:													
		1-200	8	67	542	542	8	542	0	0				
		201-500	12	291	3,495	3,495	21	2,795	3	700				
		501 and above	5	6,293	31,468	31,468	44	15,018	5	16,450				
			25	1,425	35,505	35,505	73	18,355	8	17,150				
	Purchased electric power only:													
		1-200	387	27	10,510									
		201-500	19	314	5,968									
		501 and above	14	880	12,396									
			420	69	28,874									
	All other power:													
		1-200	63	45	2,849	1,855	16	1,260	0	0	29	375	5	220
		201-500	10	288	2,882	1,630	16	1,145	0	0	7	485	0	0
		501 and above	26	5,950	155,085	83,123	67	21,880	25	59,243	3	950	5	1,050
			99	1,625	160,816	86,608	99	24,285	25	59,243	39	1,810	10	1,270
	Total power		544	414	225,195	122,113	172	42,640	33	76,393	39	1,810	10	1,270
	Grand total		574		225,195	122,113	172	42,640	33	76,393	39	1.810	10	1,270
14d. Ice, manufactured.	No power		8											
	Steam power only:													
		1-200	113	100	11,286	11,286	116	10,648	12	638				
		201-500	43	335	14,415	14,415	113	14,265	2	150				
		501 and above	49	830	40,630	40,630	278	40,135	5	495				
			205	323	66,331	66,331	507	65,048	19	1,283				
	Purchased electric power only:													
		1-200	21	83	1,747									
		201-500	12	333	3,990									
		501 and above	15	1,011	15,167									
			48	436	20,904									
	All other power:													
		1-200	46	115	5,291	4,609	42	2,385	3	210	28	1,346	5	66
		201-500	18	332	5,985	4,612	36	3,305	0	0	10	1,107	1	100
		501 and above	13	985	12,807	7,014	32	3,654	3	135	14	3,225	0	0
			77	313	24,083	16,235	110	9,344	6	345	52	5,778	6	768
	Total power		330	337	111,318	82,566	617	74,392	25	1,628	52	5,778	6	768
	Grand total		338		111,318	82,566	617	74,392	25	1,628	52	5,778	6	767
14e. Shipbuilding.	No power		43											
	Steam power only:													
		1-200	20	79	1,575	1,575	34	1,575	0	0				
		201-500	3	364	1,092	1,092	12	1,092	0	0				
		501 and above	7	4,745	33,216	33,216	42	10,500	11	22,716				
			30	1,196	35,883	35,883	88	13,167	11	22,716				
	Purchased electric power only:													
		1-200	114	3	333									
		201-500	8	326	2,608									
		501 and above	13	8,150	106,089									
			135	809	109,030									
	All other power:													
		1-200	150	35	5,215	3,127	47	1,617	1	10	154	1,453	2	47
		201-500	16	300	4,807	2,203	28	2,030	0	0	8	173	0	0
		501 and above	19	3,910	74,143	16,265	70	12,208	11	3,470	5	587	0	0
			185	347	84,165	21,595	145	15,855	12	3,480	167	2,213	2	47
	Total power		350	655	229,078	57,478	233	29,022	23	26,196	167	2,213	2	47
	Grand total		393		229,078	57,478	233	29,022	23	26,196	167	2,213	2	47

by industry subgroups, by character of power supply—Continued.

Power-supply equipment—Continued.				Electric motors.				Fuel used.			
Operated by purchased energy.								Coal.			
Total horsepower.	Electric motors.		Other (horsepower).	Total.		Run by current generated in establishment.		Anthracite (long tons).	Bituminous (short tons).	Total equivalent bituminous (short tons).	Coke (short tons).
	Number.	Horsepower.		Number.	Horsepower.	Number.	Horsepower.				
16	17	18	19	20	21	22	23	24	25.	26	27
.....	.....	.....	.....	.....	.....	.....	.....	20	254	272	.8
.....	.....	.....	.....	30	242	30	242	677	2,508	3,118	10
.....	.....	.....	.....	254	2,384	254	2,384	5,908	17,941	23,241	592
.....	.....	.....	.....	9,007	42,891	9,007	42,891	5,645	45,828	50,898	2,414
.....	.....	.....	.....	9,291	45,517	9,291	45.517	12,230	66,277	77,257	3,016
10,510	3,257	10,510	.....	3,257	10,510	.....	.....	5,963	11,061	.6,431	469
5,968	1,267	5,968	.....	1,267	5,968	.....	.....	7,041	17,820	24,140	687
12,396	1,329	12,396	.....	1,329	12,396	.....	.....	5,161	22,955	27,605	400
28,874	5,853	28,874	.....	5,853	28,874	.....	.....	18,165	51,386	68,176	1,556
994	125	767	227	233	1,239	108	472	2,938	4,170	6,810	2
1,252	316	1,252	0	389	1,797	73	545	9,743	8,042	16,802	312
71,962	12,073	71,962	0	25,421	163,894	13,348	91,932	53,991	364,960	414,360	5,782
74,208	12,514	73,981	227	26,043	166,930	13,529	92,949	66,672	377,172	437,972	6,096
103,082	18,367	102,855	227	41,187	241,321	22,820	138,466	97,067	495,285	583,405	10.668
103,082	18,367	102,855	227	41,187	241,321	22,820	138,466	97,087	495,539	583,677	10,676
.....	.....	.....	.....	.....	.....	.....	.....	7,516	13,493	20,261	0
.....	.....	.....	.....	49	482	49	482	23,875	120,156	141,648	1,000
.....	.....	.....	.....	162	1,331	162	1,331	25,270	107,876	130,619	0
.....	.....	.....	.....	369	4,576	369	4,476	81,195	229,719	302,794	0
.....	.....	.....	.....	580	6,389	580	6,389	130,340	457,751	575,061	1,000
1,747	93	1,747	.....	93	1,747	.....	.....	3,145	4,367	7,197	0
3,990	93	3,990	.....	93	3,990	.....	.....	106	388	483	0
15,167	302	15,167	.....	302	15,167	.....	.....	188	13,352	13,616	0
20,904	488	20,904	.....	488	20,904	.....	.....	3,439	18,107	21,196	0
682	70	682	0	101	869	31	187	2,755	25,526	28,005	0
1,373	70	1,373	0	124	1,935	54	562	12,293	23,386	34,447	414
5,793	72	3,843	1,950	146	4,777	74	934	14,430	20,579	33,566	0
7,848	212	5,898	1,950	371	7,581	159	1,683	29,478	69,491	96,018	414
28,752	700	26,802	1,950	1,439	34,874	739	8,072	163,257	545,349	692,375	1,414
28,752	700	26,802	1,950	1,439	34,874	739	8,072	170,773	558,842	712,536	1,414
.....	.....	.....	.....	.....	.....	.....	.....	382	45	388	0
.....	.....	.....	.....	7	60	7	60	1,063	6,902	7,877	122
.....	.....	.....	.....	110	795	110	795	2,379	5,737	7,879	0
.....	.....	.....	.....	1,341	32,009	1,341	32,009	1,252	191,739	192,864	9,906
.....	.....	.....	.....	1,458	32,864	1,458	32,864	4,714	204,378	208,620	10,028
333	328	333	.....	328	333	.....	.....	1,404	2,194	3,454	60
2,608	146	2,608	.....	146	2,608	.....	.....	6,177	2,473	8,035	114
106,089	4,674	106,089	.....	4,674	106,089	.....	.....	10,203	118,790	127,970	29,453
109,030	5,148	109,030	.....	5,148	109,030	.....	.....	17,784	123,457	139,459	29,627
2,088	172	2,073	15	172	2,073	0	0	1,225	5,392	6,494	110
2,604	151	2,394	210	155	2,569	4	175	1,897	8,517	10,227	127
57,878	3,379	57,878	0	3,517	62,147	138	4,269	8,220	154,640	162,038	15,555
62,570	3,702	62,345	225	3,844	66,789	142	4,444	11,342	168,549	178,759	15,792
171,600	8,850	171,375	225	10,450	208,683	1,600	37,308	33,840	496,384	526,838	55,447
171,600	8,850	171,375	225	10,450	208,683	1,600	37,308	34,222	496,429	527,226	55,447

TABLE 46.—*Mechanical power-supply equipment and fuel used*

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Power-supply equipment.									
						Prime movers.								
						Steam engines.		Steam turbines.		Internal-combustion engines.		Water wheels.	
					Total horse-power.	Number.	Horse-power.	Number.	Horse-power.	Number.	Horse-power.	Number.	Horse-power.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
[illegible]			[illegible]											
[illegible]			[illegible]	[illegible]	21,657	21,657	365	21,242	4	415				
			[illegible]	[illegible]	20,775	20,775	141	20,350	6	425				
			[illegible]	[illegible]	46,524	46,524	165	30,255	24	16,269				
			[illegible]	[illegible]	88,956	88,956	671	71,847	34	17,109				
[illegible]														
	[illegible]		[illegible]	42,920										
	[illegible]		[illegible]	8,535										
	[illegible]		[illegible]	11,758										
	[illegible]		13	63,213										
[illegible]			41	24,525	16,203	186	9,949	7	212	297	3,797	78	2,245
			307	23,607	14,808	119	11,694	1	250	25	1,185	19	1,679
			1,340	69,729	42,164	207	26,102	10	13,644	30	532	25	1,886
			159	117,861	73,175	512	47,745	18	14,106	352	5,514	122	5,810
Total power			45	270,030	162,131	1,183	119,592	52	31,215	352	5,514	122	5,810
Grand total				270,030	162,131	1,183	119,592	52	31,215	352	5,514	122	5,810
No power			33										
Steam power only			39	28,512	28,512	751	28,042	10	470				
			286	2,000	2,000	15	2,000	0	0				
			890	1,780	1,780	6	1,780	0	0				
			44	32,292	32,292	772	31,822	10	470				
Purchased electric power only			12	6,653									
All other power			47	12,953	9,314	203	8,475	7	153	41	588	5	98
			299	1,496	1,275	9	1,275	0	0	0	0	0	0
			564	1,693	1,490	7	990	2	500	0	0	0	0
			56	16,142	12,079	219	10,740	9	653	41	588	5	98
Total power			35	55,087	44,371	991	42,562	19	1,123	41	588	5	98
Grand total				55,087	44,371	991	42,562	19	1,123	41	588	5	98
No power			3										
Steam power only			60	3,114	3,114	123	3,114	0	0				
			312	1,560	1,560	32	1,560	0	0				
			3,130	241,085	241,085	1,298	206,175	19	34,910				
			1,830	245,759	245,759	1,453	210,849	19	34,910				
Purchased electric power only			101	2,736									
			345	4,163									
			1,580	14,240									
			440	21,139									
All other power			58	1,916	1,404	52	775	0	0	54	629	0	0
			344	2,405	1,275	32	1,260	0	0	1	15	0	0
			3,880	628,507	533,785	3,761	517,257	26	15,755	24	773	0	0
			3,130	632,828	536,464	3,845	519,292	26	15,755	79	1,417	0	0
Total power			2,340	899,726	782,223	5,298	730,141	45	50,665	79	1,417	0	0
Grand total			[illegible]	899,726	782,223	5,298	730,141	45	50,665	79	1,417	0	0

by industry subgroups, by character of power supply—Continued.

Power-supply equipment—Continued.				Electric motors.				Fuel used.			
Operated by purchased energy.				Total.		Run by current generated in establishment.		Coal.			Coke (short tons).
Total horsepower.	Electric motors.		Other (horsepower).					Anthracite (long tons).	Bituminous (short tons).	Total equivalent bituminous (short tons).	
	Number.	Horsepower.		Number.	Horsepower.	Number.	Horsepower.				
16	17	18	19	20	21	22	23	24	25	26	27
.....	.....	.....	.....	.....	.....	.....	.....	3,559	9,731	12,931	118
.....	.....	.....	.....	483	2,453	483	2,453	23,185	79,714	100,514	2,867
.....	.....	.....	.....	833	5,915	833	5,915	29,517	69,594	96,194	671
.....	.....	.....	.....	2,691	30,449	2,691	30,449	42,280	248,693	286,000	10,242
.....	.....	.....	.....	4,007	38,817	4,007	38,817	94,982	398,001	482,708	13,780
42,920	17,475	42,920	.....	17,475	42,920	.....	.....	27,649	36,968	61,768	663
8,535	569	8,535	.....	569	8,535	.....	.....	2,154	25,075	27,015	79
11,758	977	11,758	.....	977	11,758	.....	.....	2,120	30,447	32,357	0
63,213	19,021	63,213	.....	19,021	63,213	.....	.....	31,923	92,490	121,140	742
8,322	940	6,262	2,060	1,137	7,529	197	1,267	119,020	45,504	152,524	1,503
8,799	818	8,799	0	1,486	12,650	668	3,851	19,239	52,572	69,872	1,211
27,565	1,794	27,565	0	3,213	43,271	1,419	15,706	80,906	150,084	222,784	1,919
44,686	3,552	42,626	2,060	5,836	63,450	2,284	20,824	219,165	248,160	445,180	4,633
107,899	22,573	105,839	2,060	28,864	165,480	6,291	59,641	346,070	738,651	1,049,028	19,155
107,899	22,573	105,839	2,060	28,864	165,480	6,291	59,641	349,629	748,382	1,061,959	19,273
.....	.....	.....	.....	.....	.....	.....	.....	1,771	247	1,837	0
.....	.....	.....	.....	927	3,126	927	3,126	93,616	138,193	222,493	3,234
.....	.....	.....	.....	131	705	131	705	4,355	5,575	9,505	0
.....	.....	.....	.....	228	1,481	228	1,481	7,217	2,812	9,312	0
.....	.....	.....	.....	1,286	5,312	1,286	5,312	105,188	146,580	241,310	3,234
6,653	1,369	6,653	.....	1,369	6,653	.....	.....	24,478	26,357	48,357	1,131
3,639	534	2,254	1,385	972	4,268	438	2,014	37,820	46,670	80,670	467
221	102	221	0	261	634	159	413	4,959	10,806	15,266	39
203	22	203	0	243	636	221	433	4,353	3,601	7,521	0
4,063	658	2,678	1,385	1,476	5,538	818	2,860	47,132	61,077	103,457	506
10,716	2,027	9,331	1,385	4,131	17,503	2,104	8,172	176,798	234,014	393,124	4,871
10,716	2,027	9,331	1,385	4,131	17,503	2,104	8,172	178,569	234,261	394,961	4,871
.....	.....	.....	.....	.....	.....	.....	.....	90	0	80	0
.....	.....	.....	.....	2	60	2	60	17,995	2,749	18,900	0
.....	.....	.....	.....	0	0	0	0	17,441	0	15,700	0
.....	.....	.....	.....	2,595	120,983	2,595	120,983	2,734,426	0	2,460,000	0
.....	.....	.....	.....	2,597	121,043	2,597	121,043	2,769,862	2,749	2,494,600	0
2,736	91	2,736	.....	91	2,736	.....	.....	3,195	0	2,980	0
4,163	112	4,163	.....	112	4,163	.....	.....	2,361	20	2,140	0
14,240	325	14,240	.....	325	14,240	.....	.....	20,085	0	18,100	0
21,139	528	21,139	.....	528	21,139	.....	.....	25,641	20	23,220	0
512	30	512	0	30	512	0	0	1,198	1,327	2,390	0
1,130	42	1,130	0	42	1,130	0	0	24,077	0	21,700	0
94,722	1,281	94,722	0	2,449	159,422	1,168	64,700	5,731,766	25,567	5,180,000	0
96,364	1,353	96,364	0	2,521	161,064	1,168	64,700	5,757,041	26,894	5,204,090	0
117,503	1,881	117,503	0	5,646	303,246	3,765	185,743	8,552,544	29,663	7,721,910	0
117,503	1,881	117,503	0	5,646	303,246	3,765	185,743	8,552,634	29,663	7,721,990	0

TABLE 46.—*Mechanical power-supply equipment and fuel used*

Industry subgroup.	Character of power supply.	Size of plant (horsepower.)	Establishments.		Power-supply equipment.									
						Prime movers.								
							Steam engines.		Steam turbines.		Internal-combustion engines.		Water wheels.	
			Number.	Average size (horsepower).	Aggregate horsepower.	Total horsepower.	Number.	Horsepower.	Number.	Horsepower.	Number.	Horsepower.	Number.	Horsepower.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
16b. Mines and quarries except anthracite.	No power		88											
	Steam power only:													
		1-200	213	71	15,038	15,038	356	14,837	6	201				
		201-500	35	314	11,005	11,005	131	11,005	0	0				
		501 and above	14	1,223	17,158	17,158	114	14,168	5	2,990				
			262	165	43,201	43,201	601	40,010	11	3,191				
	Purchased electric power only:													
		1-200	78	72	5,629									
		201-500	8	300	2,405									
		501 and above	4	806	3,226									
			90	125	11,260									
	All other power:													
		1-200	131	71	9,315	5,863	123	4,036	0	0	93	1,352	7	475
		201-500	41	303	12,431	7,693	117	6,220	0	0	20	377	8	1,096
		501 and above	31	1,123	34,824	18,293	315	14,020	1	275	20	3,848	2	150
			203	279	56,570	31,849	555	24,276	1	275	133	5,577	17	1,721
	Total power		555	200	111,031	75,050	1,156	64,286	12	3,466	133	5,577	17	1,721
	Grand total		643		111,031	75,050	1,156	64,286	12	3,466	133	5,577	17	1,721
17. Government institutions.	Steam power only:													
		1-200	1	20	20	20	1	20	0	0				
		501 and above	8	6,480	51,856	51,856	34	19,660	20	32,196				
			9	5,760	51,876	51,876	35	19,680	20	32,196				
	Purchased electric power only:													
		1-200	13	70	906									
		201-500	1	225	225									
			14	81	1,131									
	All other power:													
		501 and above	8	6,340	49,722	25,658	24	10,648	16	14,000	4	100	3	910
	Total power		31	3,350	102,729	77,534	59	30,328	36	46,196	4	100	3	910

by industry subgroups, by character of power supply—Continued.

Power-supply equipment—Continued.				Electric motors.				Fuel used.			
Operated by purchased energy.				Total.		Run by current generated in establishment.		Coal.			Coke (short tons).
Total horsepower.	Electric motors.		Other (horsepower).					Anthracite (long tons).	Bituminous (short tons).	Total equivalent bituminous (short tons).	
	Number.	Horsepower.		Number.	Horsepower.	Number.	Horsepower.				
16	17	18	19	20	21	22	23	24	25	26	27
.....	.....	.....	.....	.....	.....	.....	.....	35	602	633	.....
.....	.....	.....	.....	8	195	8	195	5,068	60,586	65,140	41
.....	.....	.....	.....	21	386	21	386	3,720	33,484	36,830	0
.....	.....	.....	.....	62	4,367	62	4,367	27,133	47,752	72,200	12
.....	.....	.....	.....	91	4,948	91	4,948	35,921	141,822	174,170	53
5,629	173	5,629	.....	173	5,629	.....	.....	325	1,440	1,730	0
2,405	31	2,405	.....	31	2,405	.....	.....	0	669	669	0
3,226	70	3,226	.....	70	3,226	.....	.....	64	814	870	0
11,260	274	11,260	.....	274	11,260	.....	.....	389	2,923	3,269	0
3,452	136	3,452	0	136	3,452	.....	.....	2,683	17,258	19,670	41
4,738	140	4,738	0	141	4,753	1	15	1,607	18,310	19,760	50
16,531	239	16,531	0	292	19,300	53	2,769	5,198	55,212	59,880	184
24,721	515	24,721	0	569	27,505	54	2,784	9,488	90,780	99,310	275
35,981	789	35,981	0	934	43,713	145	7,732	45,798	235,525	276,749	328
35,981	789	35,981	0	934	43,713	145	7,732	45,833	236,127	277,382	328
.....	.....	.....	.....	0	0	0	0	0	1,211	1,211	781
.....	.....	.....	.....	6,732	74,478	6,732	74,478	12,822	200,078	211,618	2,025
.....	.....	.....	.....	6,732	74,478	6,732	74,478	12,822	201,289	212,829	2,806
906	460	906	.....	460	906	.....	.....	3,536	956	4,138	0
225	21	225	.....	21	225	.....	.....	340	0	306	0
1,131	481	1,131	.....	481	1,131	.....	.....	3,876	956	4,444	0
24,064	1,338	24,064	0	5,433	55,814	4,095	31,750	7,677	201,404	208,313	726
25,195	1,819	25,195	0	12,646	131,423	10,827	106,228	24,375	403,649	425,586	3,532

TABLE 47.—*Mechanical power-supply equipment,*

[Data from census of

State.	County.	Size of plant (horsepower).	Establishments reporting power.		Power-supply equipment.					
						Prime movers.				
							Steam engines.		Steam turbines.	
			Number.	Average size (horsepower).	Aggregate horsepower.	Total horsepower.	Number.	Horsepower.	Number.	Horsepower.
1	2	3	4	5	6	7	8	9	10	11
New Hampshire	Cheshire	1-200	141	51	7,209	5,573	68	4,028	3	65
		201-500	22	350	7,692	5,645	32	3,505	1	150
		501 and above	6	938	5,628	4,685	19	3,345	0	0
			169	121	20,529	15,903	119	10,878	4	215
	Hillsborough	1-200	317	33	10,558	6,568	89	4,629	2	75
		201-500	29	262	7,640	5,065	36	3,706	3	450
		501 and above	18	4,920	88,682	67,171	60	21,475	14	30,839
			364	291	106,880	78,804	185	29,810	19	31,364
	Merrimack	1-200	163	40	6,515	3,877	60	2,651	0	0
		201-500	18	316	5,685	5,035	18	2,085	0	0
		501 and above	13	1,710	22,398	18,755	48	6,315	0	0
			194	177	34,598	27,667	126	11,051	0	0
	Rockingham	1-200	164	35	5,724	4,153	71	3,476	0	0
		201-500	3	255	765	765	2	475	0	0
		501 and above	5	2,806	14,030	13,530	19	11,900	2	760
			172	119	20,519	18,448	92	15,851	2	760
Vermont	Bennington	1-200	111	41	4,546	3,712	49	2,426	0	0
		201-500	13	286	3,723	2,770	12	1,765	0	0
		501 and above	6	1,104	6,623	4,273	10	1,830	2	1,363
			130	114	14,892	10,755	71	6,021	2	1,363
	Windham	1-200	147	41	6,081	4,941	65	2,846	0	0
		201-500	15	333	4,996	3,110	18	2,170	0	0
		501 and above	5	2,572	12,862	10,930	20	2,030	0	0
			167	143	23,939	18,981	103	7,046	0	0
Massachusetts	Barnstable	1-200	31	14	432	340	8	222	1	48
		501 and above	1	925	925	900	3	900	0	0
			32	43	1,357	1,240	11	1,122	1	48
	Berkshire	1-200	221	29	6,414	3,401	54	1,871	2	100
		201-500	25	304	7,594	5,319	37	3,928	3	440
		501 and above	29	2,230	64,575	52,112	194	24,726	13	14,658
			275	285	78,583	60,832	285	30,525	18	15,198
	Bristol	1-200	815	22	18,326	6,809	115	5,543	4	135
		201-500	44	298	13,171	7,807	62	6,301	8	760
		501 and above	111	2,820	313,483	255,100	270	214,201	40	37,084
			970	354	344,980	269,716	447	226,045	52	37,979
	Dukes	1-200	12	11	126	121	3	43	0	0
			12	11	126	121	3	43	0	0
	Essex	1-200	1,497	26	38,427	10,992	180	9,889	6	240
		201-500	57	310	17,681	12,569	88	11,584	3	175
		501 and above	58	3,400	196,800	162,990	285	47,318	65	97,787
			1,612	156	252,908	186,551	553	68,791	74	98,202
	Franklin	1-200	181	37	6,699	3,523	36	1,655	1	50
		201-500	7	316	2,213	1,575	3	325	0	0
		501 and above	11	1,937	21,305	14,176	19	3,150	2	1,300
			199	150	30,217	19,274	58	5,130	3	1,350
	Hampden	1-200	652	29	18,995	7,483	95	5,758	1	75
		201-500	44	303	13,307	7,896	52	5,781	2	70
		501 and above	60	3,365	201,932	139,576	225	45,231	37	29,760
			756	310	234,235	154,955	372	56,770	40	29,905
	Hampshire	1-200	145	35	5,135	2,926	34	1,562	2	22
		201-500	12	312	3,745	2,755	14	1,935	0	0
		501 and above	12	2,865	34,380	16,958	20	4,037	5	5,947
			169	255	43,260	22,639	68	7,534	7	5,969

by counties and size of plant.

manufactures, 1919.]

Power-supply equipment—Continued.								Electric motors.				Number of establishments reporting no power.
Prime movers—Continued.				Operated by purchased energy.				Total.		Run by current generated in establishment.		
Internal-combustion engines.		Water wheels.		Total horsepower.	Electric motors.		Other (horsepower).					
Number.	Horsepower.	Number.	Horsepower.		Number.	Horsepower.		Number.	Horsepower.	Number.	Horsepower.	
12	13	14	15	16	17	18	19	20	21	22	23	24
9	133	33	1,347	1,636	236	1,636	0	237	1,639	1	3	.....
0	0	26	1,990	2,047	92	1,932	115	158	2,573	66	641	.....
0	0	10	1,340	943	69	943	0	84	1,113	15	170	.....
9	133	69	4,677	4,626	397	4,511	115	479	5,325	82	814	17
24	198	44	1,666	3,990	783	3,740	250	799	3,910	16	170	.....
0	0	9	909	2,575	273	2,575	0	502	4,249	229	1,674	.....
0	0	65	14,857	21,511	1,779	21,511	0	2,879	53,110	1,100	31,599	.....
24	198	118	17,432	28,076	2,835	27,826	250	4,180	61,269	1,345	33,443	50
8	126	34	1,100	2,638	453	2,612	26	467	2,696	14	84	.....
0	0	34	2,950	650	32	650	0	56	1,006	24	356	.....
0	0	46	12,440	3,643	470	3,643	0	562	4,337	92	694	.....
8	126	114	16,490	6,931	955	6,905	26	1,085	8,039	130	1,134	20
14	207	14	470	1,571	230	1,571	0	276	1,733	46	162	.....
2	230	2	60	0	0	0	0	15	0	15	79	.....
0	0	6	870	500	111	500	0	663	6,855	552	6,355	.....
16	437	22	1,400	2,071	341	2,071	0	954	8,667	613	6,596	24
14	102	38	1,184	834	132	834	0	132	834	0	0	.....
4	50	15	955	953	64	953	0	76	1,271	12	318	.....
0	0	11	1,080	2,350	26	2,350	0	168	3,000	142	650	.....
18	152	64	3,219	4,137	222	4,137	0	376	5,105	154	968	14
21	167	55	1,928	1,140	242	1,140	0	244	2,780	2	1,640	.....
0	0	14	940	1,886	205	1,886	0	325	2,195	120	309	.....
0	0	34	8,900	1,932	72	1,932	0	104	2,927	32	995	.....
21	167	103	11,768	4,958	519	4,958	0	673	7,902	154	2,944	7
12	59	3	11	92	10	92	0	10	92	0	0	.....
0	0	0	0	25	1	25	0	153	2,215	152	2,190	.....
12	59	3	11	117	11	117	0	163	2,307	152	2,190	20
18	347	25	1,083	3,013	512	3,001	12	559	3,144	47	143	.....
2	110	11	841	2,275	234	2,275	0	316	3,018	82	743	.....
0	0	81	12,728	12,463	847	12,463	0	5,334	49,068	4,487	36,605	.....
20	457	117	14,652	17,751	1,593	17,739	12	6,209	55,230	4,616	37,491	40
41	484	18	647	11,517	2,023	11,517	0	2,044	11,832	21	315	.....
5	221	9	525	5,364	378	5,364	0	487	7,021	109	1,657	.....
3	675	46	3,140	58,383	3,849	58,383	0	6,757	106,388	2,908	48,005	.....
49	1,380	73	4,312	75,264	6,250	75,264	0	9,288	125,241	3,038	49,977	120
9	78	0	0	5	5	5	0	7	12	2	7	.....
9	78	0	0	5	5	5	0	7	12	2	7	6
38	403	13	460	27,435	4,412	21,724	5,711	4,688	23,386	276	1,662	.....
0	0	16	810	5,112	584	5,112	0	881	8,962	297	3,850	.....
11	870	57	17,015	33,810	4,523	33,810	0	17,011	151,113	12,488	117,303	.....
49	1,273	86	18,285	66,357	9,519	60,646	5,711	22,580	183,461	13,061	122,815	210
17	216	45	1,602	3,176	629	3,176	0	757	3,804	128	628	.....
1	125	7	1,125	638	61	638	0	116	1,086	55	448	.....
0	0	31	9,726	7,129	991	7,129	0	1,128	10,319	137	3,190	.....
18	341	83	12,453	10,943	1,681	10,943	0	2,001	15,209	320	4,266	15
14	209	38	1,441	11,512	2,347	11,188	324	2,450	12,090	103	902	.....
1	3	27	2,042	5,411	630	5,411	0	1,046	7,685	416	2,274	.....
4	52	177	64,533	62,357	2,849	50,257	12,100	5,413	99,418	2,564	49,161	.....
19	264	242	68,016	79,280	5,826	66,856	12,424	8,909	119,193	3,083	52,337	135
6	127	36	1,215	2,209	334	2,209	0	399	2,310	65	101	.....
0	0	8	820	990	119	990	0	383	1,222	264	232	.....
3	635	36	6,339	17,422	1,652	17,422	0	1,850	23,534	198	6,112	.....
9	762	80	8,374	20,621	2,105	20,621	0	2,632	27,066	527	6,445	34

TABLE 47.—*Mechanical power-supply equipment,*

State.	County.	Size of plant (horsepower).	Establishments reporting power.		Power-supply equipment.					
						Prime movers.				
							Steam engines.		Steam turbines.	
			Number.	Average size (horsepower).	Aggregate horsepower.	Total horsepower.	Number.	Horsepower.	Number.	Horsepower.
1	2	3	4	5	6	7	8	9	10	11
Massachusetts (Continued.)	Middlesex	1-200	1,410	30	43,080	20,548	306	17,702	10	367
		201-500	102	304	31,020	18,936	121	16,741	6	631
		501 and above	81	2,450	198,210	143,116	352	66,246	80	47,138
			1,593	170	272,310	182,600	779	100,689	96	48,136
	Nantucket	1-200	6	27	163	163	3	163	0	0
			6	27	163	163	3	163	0	0
	Norfolk	1-200	420	33	13,902	6,215	98	5,470	1	46
		201-500	38	343	13,063	8,595	44	6,718	3	227
		501 and above	23	1,750	40,473	19,330	40	12,285	10	5,983
			481	140	67,438	34,140	182	24,473	14	6,256
	Plymouth	1-200	370	38	14,067	6,539	81	5,336	1	20
		201-500	34	321	10,906	6,120	43	4,839	3	614
		501 and above	12	1,825	21,998	17,122	29	12,375	12	4,137
			416	112	46,971	29,781	153	22,550	16	4,771
	Suffolk	1-200	2,501	18	44,293	13,368	214	11,971	5	9
		201-500	87	328	28,592	13,039	136	12,112	3	688
		501 and above	46	1,290	59,779	41,082	169	29,777	24	10,380
			2,634	50	132,664	67,489	519	53,860	32	11,077
	Worcester	1-200	1,139	39	43,997	20,451	236	15,414	3	75
		201-500	110	309	34,017	18,653	99	13,358	1	160
		501 and above	101	1,930	195,688	120,340	469	85,413	168	17,011
			1,350	202	273,702	159,444	804	114,185	172	17,186
Rhode Island	Bristol	1-200	53	17	915	259	9	251	0	0
		201-500	1	363	363	0	0	0	0	0
		501 and above	7	2,200	15,401	10,039	13	9,739	1	300
			61	272	16,679	10,298	22	9,990	1	300
	Kent	1-200	76	30	2,305	1,167	18	1,087	0	0
		201-500	5	339	1,695	1,195	6	875	0	0
		501 and above	17	1,705	29,149	29,149	77	17,659	3	2,605
			98	338	33,149	31,511	101	19,621	3	2,605
	Newport	1-200	117	16	1,859	*1,344	20	647	2	140
		201-500	1	350	350	0	0	0	0	0
		501 and above	4	2,384	9,537	9,204	8	3,425	3	5,764
			122	96	11,746	10,548	28	4,072	5	5,904
	Providence	1-200	1,549	25	38,610	11,831	207	10,111	4	91
		201-500	86	310	26,550	16,349	127	12,886	3	350
		501 and above	108	2,550	276,181	226,339	320	111,202	58	127,536
			1,743	195	341,341	254,519	654	135,199	65	127,977
	Washington	1-200	87	42	3,659	2,765	30	1,658	1	50
		201-500	14	296	4,156	3,325	20	2,170	0	0
		501 and above	6	957	5,740	4,508	71	3,300	2	900
			107	126	13,555	10,598	121	7,128	3	950
Connecticut	Fairfield	1-200	843	30	25,750	11,585	168	8,356	11	251
		201-500	41	328	13,559	7,233	40	5,233	6	583
		501 and above	48	2,140	102,591	64,848	146	34,457	39	28,300
			932	151	141,900	83,666	354	48,046	56	29,134
	Hartford	1-200	756	27	20,005	6,283	104	5,152	1	50
		201-500	68	304	20,711	12,967	77	9,172	17	524
		501 and above	57	1,640	93,719	43,435	126	26,813	13	5,991
			881	152	134,435	62,685	307	41,137	21	6,565
	Litchfield	1-200	226	30	6,760	4,730	54	2,491	1	12
		201-500	13	313	4,061	3,572	17	2,465	1	167
		501 and above	12	1,840	22,135	18,610	19	6,530	8	11,200
			251	131	32,956	26,912	90	11,386	10	11,379

by counties and size of plant—Continued.

Power-supply equipment—Continued.								Electric motors.				Number of establishments reporting no power.
Prime movers—Continued.				Operated by purchased energy.				Total.		Run by current generated in establishment.		
Internal-combustion engines.		Water wheels.		Total horsepower.	Electric motors.		Other (horsepower).					
Number.	Horsepower.	Number.	Horsepower.		Number.	Horsepower.		Number.	Horsepower.	Number.	Horsepower.	
12	13	14	15	16	17	18	19	20	21	22	23	24
80	1,413	34	1,067	22,532	4,335	20,621	1,911	4,597	22,336	262	1,715	.....
5	379	16	1,185	12,084	1,357	12,084	0	1,973	16,339	616	4,255	.....
1	10	113	29,722	55,094	3,809	55,094	0	9,511	124,198	5,702	69,104	.....
86	1,802	163	31,974	89,710	9,501	87,799	1,911	16,081	162,873	6,580	75,074	273
0	0	0	0	0	0	0	0	0	0	0	0	.....
0.	0	0	0	0	0	0	0	0	0	0	0	3
18	231	13	468	7,687	1,393	7,433	254	1,477	7,779	84	346	.....
4	453	17	1,197	4,468	363	4,468	0	671	6,018	308	1,550	.....
2	52	17	1,010	21,143	2,106	21,143	0	2,557	28,309	451	7,166	.....
24	736	47	2,675	33,298	3,862	33,044	254	4,705	42,106	843	9,062	58
19	351	29	832	7,528	1,368	6,798	730	1,444	7,427	76	629	.....
3	136	11	531	4,786	847	4,786	0	910	5,450	63	664	.....
0	0	8	610	4,876	506	4,876	0	680	8,360	174	3,484	.....
22	487	48	1,973	17,190	2,721	16,460	730	3,034	21,237	313	4,777	53
64	1,224	7	164	30,925	8,866	29,106	1,819	9,392	31,271	526	2,165	.....
6	204	1	35	15,553	2,246	15,093	460	3,259	19,044	1,013	3,951	.....
5	425	17	500	18,697	1,563	18,497	200	4,809	43,659	3,246	25,162	.....
75	1,853	25	699	65,175	12,675	62,696	2,479	17,460	93,974	4,785	31,278	698
44	842	103	4,120	23,546	4,384	23,091	455	4,694	25,223	310	2,132	.....
0	0	65	5,195	15,364	1,823	15,364	0	2,513	19,038	690	3,674	.....
2	827	76	17,079	75,348	4,151	75,348	0	6,695	106,601	2,544	31,253	.....
46	1,669	244	26,404	114,258	10,358	113,803	455	13,902	150,862	3,544	37,059	168
2	8	0	0	656	127	654	2	127	654	0	0	.....
0	0	0	0	363	6	363	0	6	363	0	0	.....
0	0	0	0	5,362	256	5,362	0	283	6,229	27	867	.....
2	8	0	0	6,381	389	6,379	2	416	7,246	27	867	15
6	55	1	25	1,138	329	1,103	35	331	1,126	2	23	.....
2	20	3	200	500	43	500	0	188	946	145	446	.....
0	0	53	8,885	0	0	0	0	382	4,534	382	4,534	.....
8	75	57	9,210	1,638	372	1,603	35	901	6,606	529	5,003	9
32	447	3	110	515	157	515	0	160	523	3	8	.....
0	0	0	0	350	45	350	0	45	350	0	0	.....
2	15	0	0	333	5	333	0	683	4,876	678	4,543	.....
34	462	3	110	1,198	207	1,198	0	888	5,749	681	4,551	25
43	652	27	977	26,779	5,315	25,458	1,321	5,606	27,666	291	2,208	.....
1	4	23	2,109	10,201	1,211	10,201	0	1,583	13,404	372	3,203	.....
6	3,125	103	14,476	49,842	4,517	49,842	0	10,670	101,936	6,153	52,094	.....
50	3,781	153	17,562	86,822	11,043	85,501	1,321	17,859	143,006	6,816	57,505	375
16	104	21	953	894	214	839	55	347	1,079	133	240	.....
2	35	23	1,120	831	64	831	0	143	1,523	79	692	.....
0	0	6	308	1,232	27	1,232	0	109	2,601	82	1,369	.....
18	139	50	2,381	2,957	305	2,902	55	599	5,203	294	2,301	15
65	1,051	33	1,927	14,165	2,400	14,165	0	2,619	15,177	219	1,012	.....
4	355	7	1,062	6,326	616	6,326	0	876	9,013	260	2,687	.....
8	869	13	1,222	37,743	2,865	37,743	0	6,369	75,237	3,704	37,494	.....
77	2,275	33	4,211	58,234	5,881	58,234	0	10,064	99,427	4,183	41,193	160
29	265	27	816	13,722	2,318	13,722	0	2,563	15,298	245	1,576	.....
12	238	43	3,033	7,744	583	7,744	0	800	9,773	217	2,029	.....
1	60	68	10,571	50,284	2,642	50,284	0	3,966	68,590	1,324	18,306	.....
42	563	138	14,420	71,750	5,543	71,750	0	7,329	93,661	1,786	21,911	181
36	545	46	1,682	2,030	288	2,018	12	472	2,941	184	923	.....
0	0	16	1,040	489	36	489	0	115	1,555	79	1,066	.....
0	0	10	880	3,525	274	3,525	0	603	13,478	329	9,953	.....
36	545	72	3,602	6,044	598	6,032	12	1,190	17,974	592	11,942	35

TABLE 46.—*Mechanical power-supply equipment and fuel used*

Industry subgroup.	Character of power supply.	Size of plant (horsepower).	Establishments.		Power-supply equipment.									
						Prime movers.								
			Number.	Average size (horsepower).	Aggregate horsepower.	Total horsepower.	Steam engines.		Steam turbines.		Internal-combustion engines.		Water wheels.	
							Number.	Horsepower.	Number.	Horsepower.	Number.	Horsepower.	Number.	Horsepower.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
14c. Electrical machinery.	No power		30											
	Steam power only:													
		1-200	8	67	542	542	8	542	0	0				
		201-500	12	291	3,495	3,495	21	2,795	3	700				
		501 and above	5	6,293	31,468	31,468	44	15,018	5	16,450				
			25	1,425	35,505	35,505	73	18,355	8	17,150				
	Purchased electric power only:													
		1-200	387	27	10,510									
		201-500	19	314	5,968									
		501 and above	14	880	12,396									
			420	69	28,874									
	All other power:													
		1-200	63	45	2,849	1,855	16	1,260	0	0	29	375	5	220
		201-500	10	288	2,882	1,630	16	1,145	0	0	7	485	0	0
		501 and above	26	5,950	155,085	83,123	67	21,880	25	59,243	3	950	5	1,050
			99	1,625	160,816	86,608	99	24,285	25	59,243	39	1,810	10	1,270
	Total power		544	414	225,195	122,113	172	42,640	33	76,393	39	1,810	10	1,270
	Grand total		574		225,195	122,113	172	42,640	33	76,393	39	1.810	10	1,270
14d. Ice, manufactured.	No power		8											
	Steam power only:													
		1-200	113	100	11,286	11,286	116	10,648	12	638				
		201-500	43	335	14,415	14,415	113	14,265	2	150				
		501 and above	49	830	40,630	40,630	278	40,135	5	495				
			205	323	66,331	66,331	507	65,048	19	1,283				
	Purchased electric power only:													
		1-200	21	83	1,747									
		201-500	12	333	3,990									
		501 and above	15	1,011	15,167									
			48	436	20,904									
	All other power:													
		1-200	46	115	5,291	4,609	42	2,385	3	210	28	1,346	5	66
		201-500	18	332	5,985	4,612	36	3,305	0	0	10	1,107	1	100
		501 and above	13	985	12,807	7,014	32	3,654	3	135	14	3,225	0	0
			77	313	24,083	16,235	110	9,344	6	345	52	5,778	6	768
	Total power		330	337	111,318	82,566	617	74,392	25	1,628	52	5,778	6	768
	Grand total		338		111,318	82,566	617	74,392	25	1,628	52	5,778	6	767
14e. Shipbuilding.	No power		43											
	Steam power only:													
		1-200	20	79	1,575	1,575	34	1,575	0	0				
		201-500	3	364	1,092	1,092	12	1,092	0	0				
		501 and above	7	4,745	33,216	33,216	42	10,500	11	22,716				
			30	1,196	35,883	35,883	88	13,167	11	22,716				
	Purchased electric power only:													
		1-200	114	3	333									
		201-500	8	326	2,608									
		501 and above	13	8,150	106,089									
			135	809	109,030									
	All other power:													
		1-200	150	35	5,215	3,127	47	1,617	1	10	154	1,453	2	47
		201-500	16	300	4,807	2,203	28	2,030	0	0	8	173	0	0
		501 and above	19	3,910	74,143	16,265	70	12,208	11	3,470	5	587	0	0
			185	347	84,165	21,595	145	15,855	12	3,480	167	2,213	2	47
	Total power		350	655	229,078	57,478	233	29,022	23	26,196	167	2,213	2	47
	Grand total		393		229,078	57,478	233	29,022	23	26,196	167	2,213	2	47

by industry subgroups, by character of power supply—Continued.

Power-supply equipment—Continued.				Electric motors.				Fuel used.			
Operated by purchased energy.				Total.		Run by current generated in establishment.		Coal.			
Total horsepower.	Electric motors. Number.	Electric motors. Horsepower.	Other (horsepower).	Number.	Horsepower.	Number.	Horsepower.	Anthracite (long tons).	Bituminous (short tons).	Total equivalent bituminous (short tons).	Coke (short tons).
16	17	18	19	20	21	22	23	24	25.	26	27
.....	.....	.....	.....	.....	.....	.....	.....	20	254	272	.8
.....	.....	.....	.....	30	242	30	242	677	2,508	3,118	10
.....	.....	.....	.....	254	2,384	254	2,384	5,908	17,941	23,241	592
.....	.....	.....	.....	9,007	42,891	9,007	42,891	5,645	45,828	50,898	2,414
.....	.....	.....	.....	9,291	45,517	9,291	45.517	12,230	66,277	77,257	3,016
10,510	3,257	10,510	.....	3,257	10,510	.....	.....	5,963	11,061	.6,431	469
5,968	1,267	5,968	.....	1,267	5,968	.....	.....	7,041	17,820	24,140	687
12,396	1,329	12,396	.....	1,329	12,396	.....	.....	5,161	22,955	27,605	400
28,874	5,853	28,874	.....	5,853	28,874	.....	.....	18,165	51,386	68,176	1,556
904	125	767	227	233	1,239	108	472	2,938	4,170	6,810	2
1,252	316	1,252	0	389	1,797	73	545	9,743	8,042	16,802	312
71,962	12,073	71,962	0	25,421	163,894	13,348	91,932	53,991	364,960	414,360	5,782
74,208	12,514	73,981	227	26,043	166,930	13,529	92,949	66,672	377,172	437,972	6,096
103,082	18,367	.102,855	227	41,187	241,321	22,820	138,466	97,067	495,285	583,405	10.668
103,082	18,367	102,855	227	41,187	241,321	22,820	138,466	97,087	495,539	583,677	10,676
.....	.....	.....	.....	.....	.....	.....	.....	7,516	13,493	20,261	0
.....	.....	.....	.....	49	482	49	482	23,875	120,156	141,648	1,000
.....	.....	.....	.....	162	1,331	162	1,331	25,270	107,876	130,619	0
.....	.....	.....	.....	369	4,576	369	4,476	81,195	223,719	302,794	0
.....	.....	.....	.....	580	6,389	580	6,389	130,340	457,751	575,061	1,000
1,747	93	1,747	.....	93	1,747	.....	.....	3,145	4,367	7,197	0
3,990	93	3,990	.....	93	3,990	.....	.....	106	388	483	0
15,167	302	15,167	.....	302	15,167	.....	.....	188	13,352	13,616	0
20,904	488	20,904	.....	488	20,904	.....	.....	3,439	18,107	21,196	0
682	70	682	0	101	869	31	187	2,755	25,526	28,005	0
1,373	70	1,373	0	124	1,935	54	562	12,293	23,386	34,447	414
5,793	72	3,843	1,950	146	4,777	74	934	14,430	20,579	33,566	0
7,848	212	5,898	1,950	371	7,581	159	1,683	29,478	69,491	96,018	414
28,752	700	26,802	1,950	1,439	34,874	739	8,072	163,257	545,349	692,375	1,414
28,752	700	26,802	1,950	1,439	34,874	739	8,072	170,773	558,842	712,536	1,414
.....	.....	.....	.....	.....	.....	.....	.....	382	45	388	0
.....	.....	.....	.....	7	60	7	60	1,063	6,902	7,877	122
.....	.....	.....	.....	110	795	110	795	2,379	5,737	7,879	0
.....	.....	.....	.....	1,341	32,009	1,341	32,009	1,252	191,739	192,864	9,906
.....	.....	.....	.....	1,458	32,864	1,458	32,864	4,714	204,378	208,620	10,028
333	328	333	.....	328	333	.....	.....	1,404	2,194	3,454	60
2,608	146	2,608	.....	146	2,608	.....	.....	6,177	2,473	8,035	114
106,089	4,674	106,089	.....	4,674	106,089	.....	.....	10,203	118,790	127,970	29,453
109,030	5,148	109,030	.....	5,148	109,030	.....	.....	17,784	123,457	139,459	29,627
2,088	172	2,073	15	172	2,073	0	0	1,225	5,392	6,494	110
2,604	151	2,394	210	155	2,569	4	175	1,897	8,517	10,227	127
57,878	3,379	57,878	0	3,517	62,147	138	4,269	8,220	154,640	162,038	15,555
62,570	3,702	62,345	225	3,844	66,789	142	4,444	11,342	168,549	178,759	15,792
171,600	8,850	171,375	225	10,450	208,683	1,600	37,308	33,840	496,384	526,838	55,447
171,600	8,850	171,375	225	10,450	208,683	1,600	37,308	34,222	496,429	527,226	55,447

TABLE 46.—*Mechanical power-supply equipment and fuel used*

Industry subgroup.	Character of power supply.	Size of plant (horsepower).	Establishments.		Power-supply equipment.									
						Prime movers.								
			Number.	Average size (horse power).	Aggregate horsepower.	Total horsepower.	Steam engines.		Steam turbines.		Internal-combustion engines.		Water wheels.	
							Number.	Horsepower.	Number.	Horsepower.	Number.	Horsepower.	Number.	Horsepower.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
14f. All other miscellaneous industries.	No power		1,834											
	Steam power only:													
		1-200	303	71	21,657	21,657	365	21,242	4	415				
		201-500	65	319	20,775	20,775	141	20,350	6	425				
		501 and above	29	1,600	46,524	46,524	165	30,255	24	16,269				
			397	223	88,956	88,956	671	71,847	34	17,109				
	Purchased electric power only:													
		1-200	4,791	9	42,920									
		201-500	31	275	8,535									
		501 and above	13	900	11,758									
			4,835	13	63,213									
	All other power:													
		1-200	607	41	24,525	16,203	186	9,949	7	212	297	3,797	78	2,245
		201-500	77	307	23,607	14,808	119	11,694	1	250	25	1,185	19	1,679
		501 and above	52	1,340	69,729	42,164	207	26,102	10	13,644	30	532	25	1,886
			736	159	117,861	73,175	512	47,745	18	14,106	352	5,514	122	5,810
	Total power		5,968	45	270,030	162,131	1,183	119,592	52	31,215	352	5,514	122	5,810
	Grand total		7,802		270,030	162,131	1,183	119,592	52	31,215	352	5,514	122	5,810
15. Laundries.	No power		33											
	Steam power only:													
		1-200	726	39	28,512	28,512	751	28,042	10	470				
		201-500	7	286	2,000	2,000	15	2,000	0	0				
		501 and above	2	890	1,780	1,780	6	1,780	0	0				
			735	44	32,292	32,292	772	31,822	10	470				
	Purchased electric power only:													
		1-200	542	12	6,653									
	All other power:													
		1-200	278	47	12,953	9,314	203	8,475	7	153	41	588	5	98
		201-500	5	299	1,496	1,275	9	1,275	0	0	0	0	0	0
		501 and above	3	564	1,693	1,490	7	990	2	500	0	0	0	0
			286	56	16,142	12,079	219	10,740	9	653	41	588	5	98
	Total power		1,563	35	55,087	44,371	991	42,562	19	1,123	41	588	5	98
	Grand total		1,590		55,087	44,371	991	42,562	19	1,123	41	588	5	98
16a. Anthracite mines.	No power		3											
	Steam power only:													
		1-200	52	60	3,114	3,114	123	3,114	0	0				
		201-500	5	312	1,560	1,560	32	1,560	0	0				
		501 and above	77	3,130	241,085	241,085	1,298	206,175	19	34,910				
			134	1,830	245,759	245,759	1,453	210,849	19	34,910				
	Purchased electric power only:													
		1-200	27	101	2,736									
		201-500	12	345	4,163									
		501 and above	9	1,580	14,240									
			48	440	21,139									
	All other power:													
		1-200	33	58	1,916	1,404	52	775	0	0	54	629	0	0
		201-500	7	344	2,405	1,275	32	1,260	0	0	1	15	0	0
		501 and above	162	3,880	628,507	533,785	3,761	517,257	26	15,755	24	773	0	0
			202	3,130	632,828	536,464	3,845	519,292	26	15,755	79	1,417	0	0
	Total power		384	2,340	899,726	782,223	5,298	730,141	45	50,665	79	1,417	0	0
	Grand total		387		899,726	782,223	5,298	730,141	45	50,665	79	1,417	0	0

by industry subgroups, by character of power supply—Continued.

Power-supply equipment—Continued.				Electric motors.				Fuel used.			
Operated by purchased energy.				Total.		Run by current generated in establishment.		Coal.			
Total horsepower.	Electric motors.		Other (horsepower).					Anthracite (long tons).	Bituminous (short tons).	Total equivalent bituminous (short tons).	Coke (short tons).
	Number.	Horsepower.		Number.	Horsepower.	Number.	Horsepower.				
16	17	18	19	20	21	22	23	24	25	26	27
.....	.....	.....	.....	.....	.....	.....	.....	3,559	9,731	12,931	118
.....	.....	.....	.....	483	2,453	483	2,453	23,185	79,714	100,514	2,867
.....	.....	.....	.....	833	5,915	833	5,915	29,517	69,504	96,194	671
.....	.....	.....	.....	2,691	30,449	2,691	30,449	42,280	248,693	286,000	10,242
.....	.....	.....	.....	4,007	38,817	4,007	38,817	94,982	398,001	482,708	13,780
42,920	17,475	42,920	.....	17,475	42,920	.....	.....	27,649	36,968	61,768	663
8,535	569	8,535	.....	569	8,535	.....	.....	2,154	25,075	27,015	79
11,758	977	11,758	.....	977	11,758	.....	.....	2,120	30,447	32,357	0
63,213	19,021	63,213	.....	19,021	63,213	.....	.....	31,923	92,490	121,140	742
8,322	940	6,262	2,060	1,137	7,529	197	1,267	119,020	45,504	152,524	1,503
8,799	818	8,799	0	1,486	12,650	668	3,851	19,239	52,572	69,872	1,211
27,565	1,794	27,565	0	3,213	43,271	1,419	15,706	80,906	150,084	222,784	1,919
44,686	3,552	42,626	2,060	5,836	63,450	2,284	20,824	219,165	248,160	445,180	4,633
107,899	22,573	105,839	2,060	28,864	165,480	6,291	59,641	346,070	738,651	1,049,028	19,155
107,899	22,573	105,839	2,060	28,864	165,480	6,291	59,641	349,629	748,382	1,061,959	19,273
.....	.....	.....	.....	.....	.....	.....	.....	1,771	247	1,837	0
.....	.....	.....	.....	927	3,126	927	3,126	93,616	138,193	222,493	3,234
.....	.....	.....	.....	131	705	131	705	4,355	5,575	9,505	0
.....	.....	.....	.....	228	1,481	228	1,481	7,217	2,812	9,312	0
.....	.....	.....	.....	1,286	5,312	1,286	5,312	105,188	146,580	241,310	3,234
6,653	1,369	6,653	.....	1,369	6,653	.....	.....	24,478	26,357	48,357	1,131
3,639	534	2,254	1,385	972	4,268	438	2,014	37,820	46,670	80,670	467
221	102	221	0	261	634	159	413	4,959	10,806	15,266	39
203	22	203	0	243	636	221	433	4,353	3,601	7,521	0
4,063	658	2,678	1,385	1,476	5,538	818	2,860	47,132	61,077	103,457	506
10,716	2,027	9,331	1,385	4,131	17,503	2,104	8,172	176,798	234,014	393,124	4,871
10,716	2,027	9,331	1,385	4,131	17,503	2,104	8,172	178,569	234,261	394,961	4,871
.....	.....	.....	.....	.....	.....	.....	.....	90	0	80	0
.....	.....	.....	.....	2	60	2	60	17,995	2,749	18,900	0
.....	.....	.....	.....	0	0	0	0	17,441	0	15,700	0
.....	.....	.....	.....	2,595	120,983	2,595	120,983	2,734,426	0	2,460,000	0
.....	.....	.....	.....	2,597	121,043	2,597	121,043	2,769,862	2,749	2,494,600	0
2,736	91	2,736	.....	91	2,736	.....	.....	3,195	0	2,980	0
4,163	112	4,163	.....	112	4,163	.....	.....	2,361	20	2,140	0
14,240	325	14,240	.....	325	14,240	.....	.....	20,085	0	18,100	0
21,139	528	21,139	.....	528	21,139	.....	.....	25,641	20	23,220	0
512	30	512	0	30	512	0	0	1,198	1,327	2,390	0
1,130	42	1,130	0	42	1,130	0	0	24,077	0	21,700	0
94,722	1,281	94,722	0	2,449	159,422	1,168	64,700	5,731,766	25,567	5,180,000	0
96,364	1,353	96,364	0	2,521	161,064	1,168	64,700	5,757,041	26,894	5,204,090	0
117,503	1,881	117,503	0	5,646	303,246	3,765	185,743	8,552,544	29,663	7,721,910	0
117,503	1,881	117,503	0	5,646	303,246	3,765	185,743	8,552,634	29,663	7,721,990	0

TABLE 47.—*Mechanical power-supply equipment,*

State.	County.	Size of plant (horsepower).	Establishments reporting power.		Power-supply equipment.					
						Prime movers.				
							Steam engines.		Steam turbines.	
			Number.	Average size (horsepower).	Aggregate horsepower.	Total horsepower.	Number.	Horsepower.	Number.	Horsepower.
1	2	3	4	5	6	7	8	9	10	11
New York (Continued.)	Schoharie	1-200	50	23	1,171	863	24	580	1	10
		201-500	1	361	361	0	0	0	0	0
		501 and above	3	1,611	4,833	3,633	8	1,633	1	2,000
			54	117	6,365	4,496	32	2,213	2	2,010
	Suffolk	1-200	134	19	2,542	1,903	34	1,462	0	0
		201-500	5	351	1,755	1,755	15	1,755	0	0
		501 and above	1	150	1,500	1,500	14	1,500	0	0
			140	41	5,797	5,158	63	4,717	0	0
	Sullivan	1-200	129	23	2,988	2,754	73	2,107	0	0
		201-500	1	480	480	480	4	365	0	0
			130	27	3,468	3,234	77	2,472	0	0
	Ulster	1-200	225	33	7,492	5,064	86	3,627	6	343
		201-500	9	277	2,496	2,056	18	2,051	0	0
		501 and above	10	1,140	11,402	7,288	16	4,670	1	50
			244	87	21,390	14,408	120	10,348	7	393
	Warren	1-200	93	40	3,754	2,133	18	1,036	0	0
		201-500	5	331	1,655	1,025	4	1,025	0	0
		501 and above	6	4,408	26,449	22,022	17	2,668	0	0
			104	305	31,858	25,180	39	4,729	0	0
	Washington	1-200	82	42	3,397	2,107	29	1,091	0	0
		201-500	10	285	2,854	1,609	10	1,065	0	0
		501 and above	15	3,222	48,326	43,568	61	10,101	1	750
			107	510	54,577	47,284	100	12,257	1	750
	West Chester	1-200	596	15	9,103	3,856	71	3,393	2	60
		201-500	23	240	7,811	3,510	32	3,350	1	100
		501 and above	20	2,233	44,656	34,875	160	25,096	32	9,742
			639	97	61,570	42,241	263	31,839	35	9,902
New Jersey	Atlantic	1-200	220	18	3,867	2,403	44	2,052	2	21
		201-500	2	415	830	830	9	830	0	0
		501 and above	1	1,000	1,000	1,000	0	0	1	1,000
			223	26	5,697	4,233	53	2,882	3	1,021
	Bergen	1-200	380	23	8,655	5,305	109	4,373	1	100
		201-500	17	353	6,023	3,235	33	3,153	2	50
		501 and above	29	1,820	52,636	49,244	197	30,461	26	17,104
			426	158	67,314	57,784	339	38,017	29	17,254
	Burlington	1-200	158	31	4,857	4,168	81	3,286	4	205
		201-500	4	384	1,537	1,262	11	1,192	2	70
		501 and above	11	2,470	27,216	23,215	56	21,535	5	690
			173	194	33,610	28,645	148	26,013	11	965
	Camden	1-200	313	33	10,211	6,479	79	4,945	10	575
		201-500	21	290	6,090	4,430	43	4,075	0	0
		501 and above	26	2,290	59,638	51,420	147	17,922	27	32,580
			360	210	75,939	62,329	269	26,942	37	33,155
	Cape May	1-200	78	22	1,720	1,353	35	914	4	135
		201-500	1	250	250	250	1	250	0	0
			79	25	1,970	1,603	36	1,164	4	135
	Cumberland	1-200	210	26	5,532	3,433	67	2,934	2	46
		201-500	6	292	1,752	613	2	135	6	478
		501 and above	3	1,857	5,512	5,510	22	2,760	2	2,350
			219	58	12,796	9,556	91	5,829	10	2,874
	Essex	1-200	2,075	26	52,862	23,913	294	19,779	2	150
		201-500	108	337	36,567	24,791	190	22,662	3	508
		501 and above	57	1,540	87,613	55,560	276	49,213	19	4,884
			2,240	79	177,042	104,264	760	91,654	25	5,542

by counties and size of plant—Continued.

Power-supply equipment—Continued.								Electric motors.				Number of establishments reporting no power.
Prime movers—Continued.				Operated by purchased energy.				Total.		Run by current generated in establishment.		
Internal-combustion engines.		Water wheels.		Total horsepower.	Electric motors.		Other (horsepower).					
Number.	Horsepower.	Number.	Horsepower.		Number.	Horsepower.		Number.	Horsepower.	Number.	Horsepower.	
12	13	14	15	16	17	18	19	20	21	22	23	24
7	92	12	181	308	47	308	0	48	312	1	4	.....
0	0	0	0	361	60	361	0	60	361	0	0	.....
0	0	0	0	1,200	12	1,200	0	67	4,137	55	2,937	.....
7	92	12	181	1,869	119	1,869	0	175	4,810	56	2,941	16
44	391	2	50	639	174	639	0	188	775	14	136	.....
0	0	0	0	0	0	0	0	64	620	64	620	.....
0	0	0	0	0	0	0	0	0	0	0	0	.....
44	391	2	50	639	174	639	0	252	1,395	78	756	79
28	325	16	322	234	46	234	0	47	239	1	5	.....
0	0	2	115	0	0	0	0	0	0	0	0	.....
28	325	18	437	234	46	234	0	47	239	1	5	22
14	86	25	1,008	2,428	353	2,413	15	401	2,806	48	393	.....
1	5	0	0	440	19	440	0	81	797	62	357	.....
6	130	15	2,438	4,114	61	4,114	0	289	7,755	228	3,641	.....
21	221	40	3,446	6,982	433	6,967	15	771	11,358	338	4,391	54
11	156	24	941	1,621	224	1,621	0	224	1,621	0	0	.....
0	0	0	0	630	6	630	0	27	1,062	21	432	.....
1	4	18	19,350	4,427	86	4,427	0	176	5,995	90	1,568	.....
12	160	42	20,291	6,678	316	6,678	0	427	8,678	111	2,000	21
6	59	21	957	1,290	280	1,290	0	309	1,470	29	180	.....
1	225	4	319	1,245	26	1,245	0	66	1,574	40	329	.....
1	20	77	32,697	4,758	225	4,758	0	593	11,430	368	6,672	.....
8	304	102	33,973	7,293	531	7,293	0	968	14,474	437	7,181	12
32	349	3	54	5,247	1,596	5,193	54	1,652	5,632	56	439	.....
1	60	0	0	4,301	358	4,301	0	1,227	5,915	869	1,614	.....
7	37	0	0	9,781	805	9,781	0	2,263	24,758	1,458	14,972	.....
40	446	3	54	19,329	2,759	19,275	54	5,142	36,300	2,383	17,025	207
28	330	0	0	1,464	466	1,459	5	544	1,791	78	332	.....
0	0	0	0	0	0	0	0	7	54	7	54	.....
0	0	0	0	0	0	0	0	221	1,157	221	1,157	.....
28	330	0	0	1,464	466	1,459	5	772	3,002	306	1,543	44
63	709	4	123	3,350	989	3,350	0	1,254	4,260	265	910	.....
1	2	0	0	2,788	200	2,788	0	313	4,316	113	1,528	.....
7	1,679	0	0	3,392	188	3,392	0	3,477	38,983	3,289	35,591	.....
71	2,390	4	123	9,530	1,377	9,530	0	5,044	47,559	3,667	38,029	84
51	487	7	190	689	174	689	0	244	981	70	292	.....
0	0	0	0	275	8	275	0	14	443	6	168	.....
2	740	1	250	4,001	178	4,001	0	929	14,693	751	10,692	.....
53	1,227	8	440	4,965	360	4,965	0	1,187	16,117	827	11,152	31
66	894	10	65	3,732	845	3,683	49	964	4,198	119	515	.....
4	255	1	100	1,660	139	1,660	0	299	3,425	160	1,765	.....
8	889	1	29	8,218	711	7,869	349	3,509	56,183	2,798	48,314	.....
78	2,038	12	194	12,610	1,695	13,212	398	4,772	63,806	3,077	50,594	80
26	304	0	0	367	86	367	0	94	436	8	69	.....
0	0	0	0	0	0	0	0	2	15	2	15	.....
26	304	0	0	367	86	367	0	96	451	10	84	13
39	305	8	148	2,099	486	2,029	70	549	2,337	63	308	.....
0	0	0	0	1,139	84	1,139	0	253	2,190	169	1,051	.....
0	0	2	400	2	0	0	2	210	3,959	310	3,959	.....
39	305	10	548	3,240	570	3,168	72	1,112	8,486	542	5,318	38
210	3,801	3	183	28,949	5,550	27,407	1,542	6,235	31,317	685	3,910	.....
47	1,505	2	116	11,776	1,665	11,776	0	2,666	20,102	1,001	8,326	.....
14	1,413	1	50	32,053	3,678	32,053	0	7,362	65,013	3,684	32,960	.....
271	6,719	6	349	72,778	10,893	71,236	1,542	16,263	116,432	5,370	45,196	447

TABLE 47.—*Mechanical power-supply equipment,*

State.	County.	Size of plant (horsepower).	Establishments reporting power.		Power-supply equipment.					
						Prime movers.				
							Steam engines.		Steam turbines.	
			Number.	Average size (horsepower).	Aggregate horsepower.	Total horsepower.	Number.	Horsepower.	Number.	Horsepower.
1	2	3	4	5	6	7	8	9	10	11
New Jersey (Continued.)	Gloucester	1-200	98	22	2,166	1,582	29	1,048	1	4
		201-500	5	360	1,800	1,569	14	945	6	624
		501 and above	4	1,449	5,795	5,195	9	1,660	14	2,297
			107	91	9,761	8,346	52	3,653	21	2,925
	Hudson	1-200	1,731	19	33,285	15,774	254	12,713	5	355
		201-500	81	334	27,135	16,446	134	14,762	7	1,100
		501 and above	79	2,200	173,345	119,763	576	78,894	62	34,118
			1,891	123	233,765	151,983	964	106,369	74	35,573
	Hunterdon	1-200	128	33	4,285	3,968	46	1,861	3	107
		201-500	6	309	1,855	1,855	13	1,600	0	0
		501 and above	6	1,765	10,593	8,095	23	3,836	3	2,300
			140	120	16,733	13,918	82	7,297	6	2,407
	Mercer	1-200	348	30	10,513	6,144	95	5,228	0	0
		201-500	28	350	9,836	7,946	64	6,788	3	733
		501 and above	27	2,120	57,277	45,712	132	30,483	17	13,043
			403	191	77,626	59,802	291	42,499	20	13,776
	Middlesex	1-200	359	26	9,450	4,932	80	4,015	3	155
		201-500	30	344	10,332	6,733	104	6,230	1	225
		501 and above	45	2,600	117,730	101,761	231	69,893	46	29,686
			434	316	137,512	113,426	415	80,138	50	30,066
	Monmouth	1-200	330	16	5,430	2,727	51	1,960	1	15
		201-500	8	339	2,712	1,856	30	1,655	3	186
		501 and above	4	871	3,484	1,868	15	523	4	1,345
			342	34	11,626	6,451	96	4,138	8	1,546
	Morris	1-200	173	24	4,078	2,885	44	2,160	1	12
		201-500	12	1,436	17,226	16,443	59	15,952	4	121
		501 and above	15	1,080	16,198	11,175	40	9,039	5	1,836
			200	188	37,502	30,503	143	27,151	10	1,969
	Ocean	1-200	72	13	965	806	13	349	3	47
		201-500	2	352	705	705	12	600	1	105
			74	23	1,670	1,511	25	949	4	152
	Passaic	1-200	1,137	23	26,544	11,443	179	9,626	20	560
		201-500	65	633	41,200	38,128	611	29,929	19	7,923
		501 and above	26	1,620	42,379	24,902	125	19,851	15	3,890
			1,328	83	110,123	74,473	915	59,406	54	12,373
	Salem	1-200	86	28	2,418	1,768	45	1,209	2	32
		201-500	2	380	761	320	4	320	0	0
		501 and above	2	6,168	12,336	12,336	37	2,361	18	9,975
			90	172	15,515	14,424	86	3,890	20	10,007
	Somerset	1-200	88	70	616	1,573	22	971	0	0
		201-500	7	350	2,452	1,209	10	1,209	0	0
		501 and above	7	1,564	10,945	10,940	14	3,840	5	7,100
			102	157	16,013	13,722	46	6,020	5	7,100
	Sussex	1-200	79	31	2,489	2,312	43	1,576	2	183
		201-500	1	250	250	250	1	150	0	0
		501 and above	3	944	2,833	2,833	15	2,250	1	450
			83	67	5,572	5,395	59	3,976	3	633
	Union	1-200	365	23	8,376	4,061	89	3,018	1	2
		201-500	32	312	10,034	5,962	54	5,380	1	250
		501 and above	21	2,560	53,881	45,898	196	19,489	51	21,751
			418	173	72,291	55,921	339	27,887	53	22,003
	Warren	1-200	145	34	4,853	3,246	49	1,758	2	95
		201-500	9	308	2,773	1,870	12	1,225	0	0
		501 and above	14	1,860	26,013	25,405	86	19,395	10	5,625
			168	200	33,639	30,521	147	22,373	12	5,720

by counties and size of plant—Continued.

Power-supply equipment—Continued.								Electric motors.				Number of establishments reporting no power.
Prime movers—Continued.				Operated by purchased energy.				Total.		Run by current generated in establishment.		
Internal-combustion engines.		Water wheels.		Total horsepower.	Electric motors.		Other (horsepower).					
Number.	Horsepower.	Number.	Horsepower.		Number.	Horsepower.		Number.	Horsepower.	Number.	Horsepower.	
12	13	14	15	16	17	18	19	20	21	22	23	24
32	354	7	176	584	104	584	0	150	780	46	196	.....
0	0	0	0	231	9	231	0	363	1,707	854	1,476	.....
5	1,208	2	30	600	2	600	0	342	5,322	340	4,722	.....
37	1,562	9	206	1,415	115	1,415	0	855	7,809	740	6,394	26
156	2,571	2	135	17,511	5,466	17,252	259	5,847	20,062	381	2,810	.....
11	584	0	0	10,689	1,072	10,689	0	2,285	18,021	1,213	7,332	.....
30	6,751	0	0	53,582	4,430	53,582	0	9,736	114,171	5,306	60,589	.....
197	9,906	2	135	81,782	10,968	81,523	259	17,868	152,254	6,900	70,731	493
45	638	43	1,362	317	92	317	0	100	392	8	75	.....
0	0	4	255	0	0	0	0	20	140	20	140	.....
4	12	6	1,947	2,498	110	2,498	0	419	6,282	309	3,784	.....
49	650	53	3,564	2,815	202	2,815	0	539	6,814	337	3,999	12
30	450	21	466	4,369	989	4,367	2	1,155	5,262	166	895	.....
2	50	5	375	1,890	160	1,620	270	545	4,093	385	2,473	.....
6	2,111	1	75	11,565	810	11,565	0	1,968	29,067	1,158	17,502	.....
38	2,611	27	916	17,824	1,959	17,552	272	3,668	38,422	1,709	20,870	108
37	572	6	190	4,518	888	4,368	150	996	5,321	108	953	.....
6	278	0	0	3,599	297	3,349	250	523	5,294	226	1,945	.....
18	2,160	2	22	15,969	1,131	15,969	0	4,291	67,247	3,160	51,278	.....
61	3,010	8	222	24,086	2,316	23,686	400	5,810	77,862	3,494	54,176	72
46	485	8	267	2,703	708	2,670	33	714	2,708	6	38	.....
4	15	0	0	856	77	856	0	77	856	0	0	.....
0	0	0	0	1,616	62	1,616	0	72	1,741	10	125	.....
50	500	8	267	5,175	847	5,142	33	863	5,305	16	163	54
17	264	16	449	1,193	281	1,193	0	385	1,458	104	265	.....
0	0	4	370	783	42	783	0	410	4,206	368	3,423	.....
2	15	5	285	5,023	79	5,023	0	523	12,574	444	7,551	.....
19	279	25	1,104	6,999	402	6,999	0	1,318	18,238	916	11,239	33
33	299	4	111	159	68	159	0	68	159	0	0	.....
0	0	0	0	0	0	0	0	2	6	2	6	.....
33	299	4	111	159	68	159	0	70	165	2	6	19
82	1,041	12	216	15,101	3,161	12,409	2,692	3,454	14,840	293	2,431	.....
5	161	2	115	3,072	378	2,597	475	1,223	6,902	845	4,305	.....
4	811	4	350	17,477	1,253	17,477	0	3,849	48,467	2,596	30,990	.....
91	2,013	18	681	35,650	4,792	32,483	3,167	8,526	70,209	3,734	37,726	209
23	168	13	359	650	103	650	0	108	724	5	74	.....
0	0	0	0	441	29	441	0	96	831	67	390	.....
0	0	0	0	0	0	0	0	434	7,681	434	7,681	.....
23	168	13	359	1,091	132	1,091	0	638	9,236	506	8,145	19
20	307	9	295	1,043	329	1,043	0	416	1,253	87	210	.....
0	0	0	0	1,243	79	1,243	0	109	1,536	30	293	.....
0	0	0	0	5	1	5	0	476	6,943	475	6,938	.....
20	307	9	295	2,291	409	2,291	0	1,001	9,732	592	7,441	20
27	306	7	247	177	157	177	0	195	542	38	365	.....
7	100	0	0	0	0	0	0	6	60	6	60	.....
1	8	2	125	0	0	0	0	38	292	38	292	.....
35	414	9	372	177	157	177	0	239	894	82	717	11
55	1,021	1	20	4,315	974	4,315	0	1,073	4,961	99	646	.....
23	332	0	0	4,072	505	4,072	0	714	5,846	209	1,774	.....
18	4,658	0	0	7,983	547	7,983	0	2,677	39,787	2,130	31,804	.....
96	6,011	1	20	16,370	2,026	16,370	0	4,464	50,594	2,438	34,224	69
37	1,398	0	0	1,607	322	1,607	0	531	2,264	209	657	.....
7	645	0	0	903	43	903	0	132	2,131	89	1,228	.....
2	385	0	0	608	13	608	0	946	16,116	933	15,508	.....
46	2,428	0	0	3,118	378	3,118	0	1,609	20,511	1,231	17,393	13

TABLE 47.—*Mechanical power-supply equipment,*

State.	County.	Size of plant (horsepower).	Establishments reporting power.		Power-supply equipment.					
						Prime movers.				
			Number.	Average size (horsepower).	Aggregate horsepower.	Total horsepower.	Steam engines.		Steam turbines.	
							Number.	Horsepower.	Number.	Horsepower.
1	2	3	4	5	6	7	8	9	10	11
Pennsylvania	Berks	1-200	780	29	22,881	11,835	252	9,488	7	168
		201-500	30	312	9,357	4,719	48	4,583	2	136
		501 and above	40	1,549	61,954	47,897	205	45,442	10	1,790
			850	110	94,192	64,451	505	59,513	19	2,094
	Bucks	1-200	359	24	8,486	6,436	124	4,575	4	292
		201-500	5	278	1,390	1,387	14	1,312	1	75
		501 and above	8	1,888	15,107	14,857	26	8,684	5	5,743
			372	67	24,983	22,680	164	14,571	10	6,110
	Carbon	1-200	94	43	4,034	2,348	35	1,443	1	8
		201-500	5	336	1,682	1,285	9	785	0	0
		501 and above	14	3,630	50,686	38,424	102	21,649	6	16,675
			113	498	56,402	42,057	146	23,877	7	16,683
	Chester	1-200	278	36	10,005	6,490	114	5,067	5	81
		201-500	20	303	6,053	4,460	33	3,790	4	575
		501 and above	15	6,670	101,944	89,258	355	65,816	44	16,082
			313	377	118,002	100,208	502	74,673	53	16,738
	Columbia	1-200	165	30	5,007	3,781	60	2,323	2	30
		201-500	9	265	2,387	1,787	13	1,257	3	305
		501 and above	5	3,545	18,725	11,930	68	11,215	1	500
			179	145	26,119	17,498	141	14,795	6	835
	Dauphin	1-200	356	25	9,060	5,434	157	4,905	2	40
		201-500	28	302	8,464	4,405	39	3,615	3	170
		501 and above	18	7,000	125,845	109,479	310	76,806	5	9,040
			402	355	143,369	119,318	506	85,326	10	9,250
	Delaware	1-200	214	37	7,833	5,869	76	4,935	0	0
		201-500	24	341	8,215	6,961	44	6,090	2	266
		501 and above	35	3,840	134,854	39,934	227	23,876	26	15,343
			273	550	150,902	52,764	347	34,901	28	15,609
	Lackawanna	1-200	384	37	14,294	3,752	72	3,611	3	30
		201-500	42	293	12,291	4,619	64	4,578	0	0
		501 and above	77	2,320	179,597	163,966	914	140,746	14	23,220
			503	410	206,182	172,337	1,050	148,935	17	23,250
	Lancaster	1-200	670	31	20,991	10,845	156	7,260	8	161
		201-500	22	314	6,946	2,137	21	2,137	0	0
		501 and above	15	1,510	22,707	10,347	68	9,978	4	312
			707	72	50,644	23,329	245	19,375	12	473
	Lebanon	1-200	242	34	8,145	4,377	100	3,521	0	0
		201-500	11	290	3,194	1,815	25	1,815	0	0
		501 and above	9	5,655	51,059	49,275	148	36,000	7	9,675
			262	237	62,398	55,467	273	41,336	7	9,675
	Lehigh	1-200	430	36	15,329	9,363	161	7,490	1	20
		201-500	27	300	8,104	4,395	61	3,796	4	220
		501 and above	26	2,750	71,140	50,546	184	50,493	0	0
			483	195	94,573	64,304	406	61,779	5	240
	Luzerne	1-200	465	30	13,752	6,727	143	5,943	1	110
		201-500	36	334	12,026	6,015	56	6,015	0	0
		501 and above	102	3,060	311,995	267,720	1,708	245,042	22	22,568
			603	560	337,773	280,462	1,907	257,000	23	22,678
	Monroe	1-200	78	36	2,792	1,975	34	1,345	1	630
		201-500	4	232	929	390	3	210	0	0
		501 and above	1	1,651	1,651	1,200	3	300	0	0
			83	65	5,372	3,565	40	1,855	1	630
	Montgomery	1-200	573	36	20,446	12,667	215	10,754	4	1,913
		201-500	31	306	9,515	6,330	44	6,043	0	0
		501 and above	30	3,055	91,658	72,482	188	45,247	41	26,572
			634	192	121,619	91,479	447	62,044	45	28,485

by counties and size of plant—Continued.

Power-supply equipment—Continued.								Electric motors.				
Prime movers—Continued.				Operated by purchased energy.				Total.		Run by current generated in establishment.		Number of establishments reporting no power.
Internal-combustion engines.		Water wheels.		Total horsepower.	Electric motors.		Other (horsepower).					
Number.	Horsepower.	Number.	Horsepower.		Number.	Horsepower.		Number.	Horsepower.	Number.	Horsepower.	
12	13	14	15	16	17	18	19	20	21	22	23	24
73	915	64	1,264	11,046	2,395	11,046	0	2,541	11,766	146	720	.....
0	0	0	0	4,638	821	4,638	0	879	5,356	58	718	.....
4	540	2	125	14,057	808	14,057	0	2,424	34,543	1,616	20,486	.....
77	1,455	66	1,389	29,741	4,024	29,741	0	5,844	51,665	1,820	21,924	216
102	911	23	658	2,050	391	2,023	27	456	2,362	65	339	.....
0	0	0	0	3	2	3	0	26	158	24	155	.....
2	30	2	400	250	2	250	0	540	11,953	538	11,703	.....
104	941	25	1,058	2,303	395	2,276	27	1,022	14,473	627	12,197	136
17	432	9	465	1,686	164	1,656	30	164	1,656	0	0	.....
0	0	6	500	397	18	397	0	18	397	0	0	.....
0	0	2	100	12,262	334	12,262	0	1,008	34,338	674	22,076	.....
17	432	17	1,065	14,345	516	14,315	30	1,190	36,391	674	22,076	19
24	346	49	996	3,515	591	3,430	85	630	3,719	39	289	.....
0	0	3	95	1,593	52	1,593	0	113	2,360	61	767	.....
8	7,270	3	90	12,686	495	12,686	0	2,119	48,585	1,634	36,899	.....
32	7,616	55	1,181	17,794	1,138	17,709	85	2,862	55,664	1,724	37,955	44
37	325	38	1,103	1,226	195	1,226	0	201	1,291	6	65	.....
0	0	7	225	600	146	600	0	158	885	12	285	.....
5	215	0	0	6,795	342	6,795	0	1,026	13,490	684	6,695	.....
42	540	45	1,328	8,621	683	8,621	0	1,385	15,666	702	7,045	18
29	148	14	341	3,626	1,021	3,626	0	1,072	3,954	51	328	.....
10	620	0	0	4,059	330	4,059	0	790	5,536	460	1,477	.....
24	23,633	0	0	16,366	814	16,366	0	3,707	76,640	2,893	60,274	.....
63	24,401	14	341	24,051	2,165	24,051	0	5,569	86,130	3,404	62,079	62
49	668	9	266	1,964	359	1,964	0	402	2,355	43	391	.....
6	425	3	180	1,254	132	1,254	0	442	4,916	310	3,662	.....
5	590	4	125	94,920	4,539	94,920	0	6,387	119,638	1,848	24,718	.....
60	1,683	16	571	98,138	5,030	98,138	0	7,231	126,909	2,201	28,771	46
11	68	2	43	10,542	1,480	10,452	90	1,550	10,648	70	196	.....
0	0	3	41	7,672	618	7,672	0	709	8,975	91	1,303	.....
0	0	0	0	15,631	557	15,631	0	2,743	100,923	2,186	85,292	.....
11	68	5	84	33,845	2,655	33,755	90	5,002	120,546	2,347	86,791	74
73	848	122	2,576	10,146	1,741	10,126	20	1,967	11,298	226	1,172	.....
0	0	0	0	4,809	449	4,809	0	469	4,849	20	40	.....
2	17	2	40	12,360	1,494	12,360	0	1,595	14,019	101	1,659	.....
75	865	124	2,616	27,315	3,684	27,295	20	4,031	30,166	347	2,871	231
39	290	28	566	3,768	619	3,768	0	651	4,138	32	370	.....
0	0	0	0	1,379	73	1,379	0	139	3,108	66	1,729	.....
3	3,600	0	0	1,784	61	1,784	0	533	18,553	472	16,769	.....
42	3,890	28	566	6,931	753	6,931	0	1,323	25,799	570	18,868	66
31	374	46	1,479	5,966	1,540	5,791	175	1,600	6,451	60	660	.....
2	214	1	165	3,709	849	3,709	0	934	4,288	85	579	.....
7	27	2	26	20,594	901	20,594	0	1,067	22,777	166	2,183	.....
40	615	49	1,670	30,269	3,290	30,094	175	3,601	33,516	311	3,422	100
35	311	10	363	7,025	1,469	7,025	0	1,600	7,766	131	741	.....
0	0	0	0	6,011	649	6,011	0	1,274	8,502	625	2,491	.....
7	110	0	0	44,275	2,949	44,275	0	4,930	124,098	1,981	79,823	.....
42	421	10	363	57,311	5,067	57,311	0	7,804	140,366	2,737	83,055	85
22	352	11	216	817	286	817	0	287	837	1	20	.....
0	0	3	180	539	39	539	0	39	539	0	0	.....
0	0	3	900	451	13	451	0	13	451	0	0	.....
22	352	17	1,296	1,807	338	1,807	0	339	1,827	1	20	17
74	789	42	939	7,779	1,269	7,779	0	1,464	9,346	195	1,567	.....
2	37	1	250	3,185	258	3,185	0	487	5,944	229	2,759	.....
3	665	0	0	19,176	1,257	19,176	0	3,401	60,927	2,144	41,751	.....
79	1,491	43	1,189	30,140	2,784	30,140	0	5,352	76,217	2,568	46,077	120

TABLE 47.—*Mechanical power-supply equipment.*

State.	County.	Size of plant (horsepower).	Establishments reporting power.		Power-supply equipment.					
						Prime movers.				
							Steam engines.		Steam turbines.	
			Number.	Average size (horsepower).	Aggregate horsepower.	Total horsepower.	Number.	Horsepower.	Number.	Horsepower.
1	2	3	4	5	6	7	8	9	10	11
Pennsylvania (Continued.)	Montour	1-200	37	22	815	495	11	315	1	50
		201-500	2	239	478	327	3	300	2	27
		501 and above	6	1,190	7,133	6,775	43	6,775	0	0
			45	187	8,426	7,597	57	7,390	3	77
	Northampton	1-200	338	42	14,173	7,794	151	6,341	2	24
		201-500	37	305	11,316	6,124	111	5,985	0	0
		501 and above	38	5,550	211,730	170,869	327	103,481	42	18,588
			413	575	237,219	184,787	589	115,807	44	18,612
	Northumberland	1-200	256	33	8,422	4,907	95	4,444	3	100
		201-500	15	317	4,757	3,115	43	3,115	0	0
		501 and above	29	3,370	97,736	92,359	699	85,969	3	6,150
			300	369	110,915	100,381	837	93,528	6	6,250
	Philadelphia	1-200	6,334	19	122,520	67,618	931	54,250	20	754
		201-500	234	320	74,929	58,113	476	55,558	6	710
		501 and above	177	1,930	342,513	231,172	1,137	188,950	73	35,582
			6,745	80	539,962	356,903	2,544	298,758	99	37,046
	Pike	1-200	18	23	409	389	8	219	1	50
		501 and above	1	2,598	2,598	2,598	27	2,008	0	0
			19	158	3,007	2,987	35	2,227	1	50
	Schuylkill	1-200	373	25	9,130	5,344	125	4,581	4	83
		201-500	15	315	4,732	3,080	65	2,980	0	0
		501 and above	69	4,250	293,142	246,779	1,612	241,970	11	4,627
			459	670	307,004	255,203	1,802	249,531	15	4,710
	Susquehanna	1-200	62	28	1,723	1,197	24	951	0	0
		201-500	1	255	255	250	1	250	0	0
		501 and above	1	1,868	1,868	900	2	900	0	0
			64	60	3,846	2,347	27	2,101	0	0
	Wayne	1-200	146	30	4,429	3,699	71	2,348	1	16
		201-500	1	450	450	450	1	450	0	0
		501 and above	3	1,871	5,614	5,144	29	4,444	0	0
			150	70	10,493	9,293	101	7,242	1	16
	Wyoming	1-200	45	32	1,424	1,338	18	775	0	0
		201-500	3	337	1,010	1,010	18	1,010	0	0
		501 and above	1	1,400	1,400	1,400	4	1,400	0	0
			49	78	3,834	3,748	40	3,185	0	0
	York	1-200	563	34	18,995	11,450	205	9,164	0	0
		201-500	32	300	9,584	6,612	41	6,308	2	100
		501 and above	18	1,810	32,675	13,199	65	7,352	5	2,450
			613	100	61,254	31,261	311	22,824	7	2,550
Delaware	Kent	1-200	104	29	3,042	2,895	80	1,995	2	20
		201-500	1	273	273	273	7	220	0	0
		501 and above	0	0	0	0	0	0	0	0
			105	32	3,315	3,168	87	2,215	2	20
	New Castle	1-200	262	42	10,961	7,676	125	6,732	1	2
		201-500	16	316	5,064	4,421	50	3,136	4	500
		501 and above	29	2,040	59,182	44,274	173	29,610	14	12,508
			307	245	75,207	56,371	348	39,478	19	13,010
District of Columbia		1-200	439	22	9,865	4,311	54	3,131	0	0
		201-500	12	294	3,539	2,390	26	2,145	2	145
		501 and above	14	3,550	49,764	35,582	66	13,369	20	20,613
			465	135	63,163	42,283	146	18,645	22	20,758

by counties and size of plant—Continued.

Power-supply equipment—Continued.								Electric motors.				Number of establishments reporting no power.
Prime movers—Continued.				Operated by purchased energy.				Total.		Run by current generated in establishment.		
Internal-combustion engines.		Water wheels.		Total horsepower.	Electric motors.		Other (horsepower).					
Number.	Horsepower.	Number.	Horsepower.		Number.	Horsepower.		Number.	Horsepower.	Number.	Horsepower.	
12	13	14	15	16	17	18	19	20	21	22	23	24
7	79	4	51	320	67	320	0	67	320	0	0	.....
0	0	0	0	151	32	151	0	32	151	0	0	.....
0	0	0	0	358	18	358	0	19	363	1	5	.....
7	79	4	51	829	117	829	0	118	834	1	5	13
21	195	41	1,224	6,379	1,392	6,379	0	1,443	7,021	51	642	.....
2	4	2	135	5,192	325	5,192	0	347	5,437	22	245	.....
23	48,500	4	300	40,861	2,134	40,861	0	10,038	232,743	7,904	191,882	.....
46	48,699	47	1,669	52,432	3,851	52,432	0	11,828	245,201	7,977	192,769	49
25	270	4	93	3,515	560	3,515	0	677	3,904	117	389	.....
0	0	0	0	1,642	36	1,642	0	407	1,860	371	218	.....
6	240	0	0	5,377	203	5,377	0	1,283	20,889	1,080	15,512	.....
31	510	4	93	10,534	799	10,534	0	2,367	26,653	1,568	16,119	41
807	12,525	9	89	54,902	15,110	48,915	5,987	17,201	59,801	2,091	10,886	.....
20	1,685	3	160	16,816	1,925	16,201	615	5,216	38,649	3,291	22,448	.....
17	4,640	3	2,000	111,341	9,062	111,341	0	20,213	241,732	11,151	130,391	.....
844	18,850	15	2,249	183,059	26,097	176,457	6,602	42,630	340,182	16,533	163,725	2,427
8	45	3	75	20	1	20	0	1	20	0	0	.....
5	590	0	0	0	0	0	0	0	0	0	0	.....
13	635	3	75	20	1	20	0	1	20	0	0	11
41	398	14	282	3,786	773	3,786	0	811	4,059	38	273	.....
4	100	0	0	1,652	110	1,652	0	186	2,366	76	714	.....
9	182	0	0	46,363	520	46,363	0	1,008	66,935	488	20,572	.....
54	680	14	282	51,801	1,403	51,801	0	2,005	73,360	602	21,559	90
11	161	3	85	526	73	526	0	73	526	0	0	.....
0	0	0	0	5	2	5	0	26	218	24	213	.....
0	0	0	0	968	46	968	0	46	968	0	0	.....
11	161	3	85	1,499	121	1,499	0	145	1,712	24	213	17
13	121	33	1,214	730	130	862	48	148	831	18	149	.....
0	0	0	0	0	0	0	0	0	0	0	0	.....
0	0	2	700	470	81	470	0	288	2,822	207	2,352	.....
13	121	35	1,914	1,200	211	1,152	48	436	3,653	225	2,501	21
17	179	11	384	86	10	46	40	10	46	0	0	.....
0	0	0	0	0	0	0	0	2	30	2	30	.....
0	0	0	0	0	0	0	0	44	751	44	751	.....
17	179	11	384	86	10	46	40	56	827	46	781	5
89	670	83	1,616	7,545	1,336	7,450	95	1,555	8,713	219	1,263	.....
6	204	0	0	2,972	309	2,972	0	513	4,264	204	1,292	.....
2	7	18	3,390	19,476	1,577	19,476	0	1,600	19,965	23	489	.....
97	881	101	5,006	29,993	3,222	29,898	95	3,668	32,942	446	3,044	428
33	504	18	376	147	59	147	0	64	197	5	50	.....
4	53	0	0	0	0	0	0	0	0	0	0	.....
0	0	0	0	0	5	0	0	5	0	0	0	.....
37	557	18	376	147	64	147	0	69	197	5	50	6
18	222	22	720	3,285	699	3,240	45	723	3,456	24	216	.....
6	160	6	625	643	73	643	0	177	1,768	104	1,125	.....
3	15	3	2,141	14,908	760	14,908	0	2,272	38,522	1,512	23,614	.....
27	397	27	3,486	18,836	1,532	18,791	45	3,172	43,746	1,640	24,955	59
55	739	3	441	5,554	2,048	5,544	10	2,174	6,039	126	495	.....
0	0	1	100	1,149	121	1,149	0	247	2,412	126	1,263	.....
6	1,475	1	125	14,182	1,041	14,182	0	7,070	68,987	6,029	54,805	.....
61	2,214	5	666	20,885	3,210	20,875	10	9,491	77,438	6,281	56,563	170

TABLE 47.—*Mechanical power-supply equipment,*

State.	County.	Size of plant (horsepower).	Establishments reporting power.		Power-supply equipment.					
						Prime movers.				
							Steam engines.		Steam turbines.	
			Number.	Average size (horsepower).	Aggregate horsepower.	Total horsepower.	Number.	Horsepower.	Number.	Horsepower.
1	2	3	4	5	6	7	8	9	10	11
Maryland	Anne Arundel	1-200	44	25	1,075	685	28	531	1	10
		201-500	2	299	597	250	1	250	0	0
		501 and above	2	983	1,965	0	0	0	0	0
			48	76	3,637	935	29	781	1	10
	Baltimore	1-200	90	25	2,285	1,646	38	1,146	0	0
		201-500	6	301	1,808	1,492	22	1,492	0	0
		501 and above	7	15,300	107,089	83,870	11	21,470	13	4,495
			103	1,080	111,182	87,008	71	24,108	13	4,495
	Baltimore City	1-200	1,863	38	70,862	18,411	295	16,035	5	315
		201-500	99	317	31,412	18,659	161	17,787	7	271
		501 and above	74	1,730	128,473	41,591	413	35,342	28	4,153
			2,036	113	230,747	78,661	869	69,164	40	4,739
	Cecil	1-200	78	36	2,854	2,455	50	1,638	0	0
		501 and above	6	884	5,308	5,308	76	4,880	0	0
			84	97	8,162	7,763	126	6,518	0	0
	Harford	1-200	164	24	3,961	3,295	132	2,190	1	15
		201-500	5	282	1,410	1,380	13	780	0	0
		501 and above	1	750	750	750	0	0	1	750
			170	36	6,121	5,425	145	2,970	2	765
	Kent	1-200	44	35	1,548	1,541	34	1,149	1	12
			44	35	1,548	1,541	34	1,149	1	12
	Prince Georges	1-200	46	16	746	734	32	620	0	0
			46	16	746	734	32	620	0	0
	Queen Annes	1-200	41	24	1,002	933	32	766	0	0
			41	24	1,002	933	32	766	0	0

by counties and size of plant—Continued.

Power-supply equipment—Continued.								Electric motors.				Number of establishments reporting no power.
Prime movers—Continued.				Operated by purchased energy.				Total.		Run by current generated in establishment.		
Internal-combustion engines.		Water wheels.		Total horsepower.	Electric motors.		Other (horsepower).					
Number.	Horsepower.	Number.	Horsepower.		Number.	Horsepower.		Number.	Horsepower.	Number.	Horsepower.	
12	13	14	15	16	17	18	19	20	21	22	23	24
3	144	0	0	390	80	390	0	81	399	1	9	.....
0	0	0	0	347	25	347	0	25	347	0	0	.....
0	0	0	0	1,965	51	1,965	0	51	1,965	0	0	.....
3	144	0	0	2,702	156	2,702	0	157	2,711	1	9	7
15	96	20	404	639	63	635	4	83	792	20	157	.....
0	0	0	0	316	101	316	0	101	316	0	0	.....
17	55,700	11	2,205	23,219	698	23,219	0	2,745	133,314	2,047	110,095	.....
32	55,796	31	2,609	24,174	862	24,170	4	2,929	134,422	2,067	110,252	28
138	1,887	3	174	52,451	6,011	52,342	109	6,511	54,709	500	2,367	.....
16	601	0	0	12,753	1,059	12,753	0	1,824	17,996	765	5,243	.....
10	2,096	0	0	86,882	5,555	86,882	0	6,427	97,128	872	10,256	.....
164	4,584	3	174	152,086	12,625	151,977	109	14,762	169,843	2,137	17,866	796
23	180	23	637	399	38	399	0	69	491	31	92	.....
7	128	2	300	0	0	0	0	15	193	15	193	.....
30	308	25	937	399	38	399	0	84	684	46	285	12
41	389	24	701	666	77	666	0	77	666	0	0	.....
0	0	2	600	30	2	30	0	2	30	0	0	.....
0	0	0	0	0	0	0	0	12	745	12	745	.....
41	389	26	1,301	696	79	696	0	91	1,441	12	745	11
24	249	6	131	7	2	7	0	3	9	1	2	.....
24	249	6	131	7	2	7	0	3	9	1	2	1
14	114	0	0	12	6	12	0	6	12	0	0	.....
14	114	0	0	12	6	12	0	6	12	0	0	23
11	69	6	98	69	10	69	0	10	69	0	0	.....
11	69	6	98	69	10	69	0	10	69	0	0	3

	Power an				
Coke (short tons).	Factor A.[a]	Energy developed by prime movers (column 7) in thousands of equivalent kilowatt-hours.	Factor B.[b]	Energy purchased for power (column 16) in thousands of kilowatt-hours.	Portion mov umn 7 water that m been by sup Per cent of column 7 minus column 15.
27	28	29	30	31	32
7,637	2,200	73,000	2,000	34,000	81
84	820	37,000	820	10,300	99
76,963	850	15,800	700	30,000	92
180	3,030	107,000	.....	.....	.....
5,514	740	73,000	740	59,000	91
16,426	1,350	960,000	1,350	245,000	87
158	1,000	53,400	900	32,400	37
383	1,000	80,000	900	53,000	74
1,994	1,300	412,000	1,300	80,000	20
300	1,040	26,800	1,040	6,500	29
1,215	1,000	119,000	850	20,000	23
18,502	1,200	98,000	1,200	27,500	65
9,348	650	17,000	650	37,300	60
4,002	1,300	30,600	1,300	31,800	54
3,170,821	2,400	430,000	1,000	400	.....
88,698	1,000	490,000	1,000	81,500	38
20,380	1,100	25,000	825	40,000	77
565,304	940	450,000	780	342,000	97
275	740	52,700	720	3,500	.....
10,881	620	83,500	480	33,200	88
2,420	1,500	88,000	1,500	45,000	17
846	800	36,600	900	39,800	80
10,013	3,000	1,278,000	3,000	168,000	49
1,313	1,200	38,500	1,000	24,000	94
1,852	1,200	38,000	1,000	136,700	100
5,140	470	48,000	470	5,700	71
36,945	600	12,000	600	12,000	75
0	1,500	21,000	1,500	5,200	100
608,629	600	62,000	600	2,600	60
222,156	1,300	85,000	1,300	2,000	23
39,840	1,500	277,000	1,500	158,000	65
1,586	4,000	460,000	4,000	190,000	25
53,438	700	29,000	580	20,200	97
6,622	520	35,000	520	13,700	91
6,591	1,740	10,000	1,600	11,600	83
329,395	3,400	665,000	2,800	280,000	90
9,837	1,350	67,800	1,120	65,000	95
908	960	8,400	960	6,300	100
1,213	1,080	17,400	900	38,000	95
8,744	1,200	6,500	1,200	20,600	100
622	760	5,100	760	5,800	100
205,085	2,000	135,000	2,000	65,000	100
1	800	640	800	15,000	100
9,220	910	30,000	910	21,600	94
4,006	1,500	132,000	1,250	109,000	83
10,676	1,500	183,000	1,250	129,000	76
1,414	2,600	215,000	2,400	68,000	96
55,447	1,800	102,000	1,200	205,000	100
19,273	1,060	172,000	1,060	115,000	87
4,871	800	35,500	800	8,600	23
0	1,550	1,215,000	1,040	123,000	100
328	780	58,500	780	28,000	100
3,532	1,390	108,000	1,240	31,000	100,
5,661,028	1,490	9,311,440	1,200	3,338,800	70

ANALYSIS OF INDUSTRIES.

GENERAL FEATURES.

In order to determine the quantity of coal that might be saved and the amount of power that might have been economically supplied by purchased energy, the detailed statistics of the industries shown in Table 46 were submitted to several engineers and manufacturers, who analyzed the data and gave their opinions as to the amount of energy that might have been economically purchased and the resulting saving of fuel. In the estimates made by this survey due regard has been given to the opinions thus obtained.

The results of this analysis are shown in Table 48. The headings for columns 5 to 27 in Table 48 are the same as the corresponding headings in Tables 44, 45, and 46. Other columns are explained as follows:

Column 29 is column 7 multiplied by column 28.

Column 31 is column 16 multiplied by column 30.

Column 32 is the ratio, in per cent, of column 33 to the difference between column 7 and column 15.

For each size of power plant in each industry the prime mover that might have been replaced by superpower was determined. The sum of these items is shown in column 33.

Column 34 shows the motor horsepower per prime-mover horsepower as determined by the authorities consulted.

Column 35 is column 33 multiplied by column 34.

Column 36 is column 35 multiplied by factor B (column 30).

Column 37 is ratio in per cent of column 38 to column 26.

Column 43 is based on a consumption by the superpower system of 2 pounds of coal per kilowatt-hour delivered at the motor leads. Column $43 = \frac{\text{column } 36 \times 1000 \times 2}{2000}$.

Column 44 equals column 40 minus column 43.

This table shows that the energy developed by prime movers in the industries in 1919 was equivalent to 9,311,440,000 kilowatt-hours and that the energy purchased was 3,338,800,000 kilowatt-hours, a total of 12,650,240,000 kilowatt-hours; also that it would have been economical to shut down 4,008,200 horsepower of prime movers, exclusive of water wheels, and to purchase additional energy to the amount of 5,623,800,000 kilowatt-hours, which would have made a total of 8,962,600,000 kilowatt-hours of purchased electrical energy.

The total coal used for power by prime movers that might have been replaced by superpower and the coal used in conjunction with them for heating and in manufacturing processes was 29,818,000 tons, of which 19,125,900 tons was used for power and 10,692,100 tons for heating and in manufacturing processes. If the energy developed by these prime movers had been purchased, the 19,125,900 tons of coal burned for power would have been replaced by 5,623,800 tons burned at the central stations (at the rate of 2 pounds of coal per kilowatt-hour as measured at the motor leads), a saving of 13,502,100 tons. That is, 71 per cent of the coal used for power by the prime movers or 25 per cent of the total coal used by the industries might have been saved.

In estimating the fuel saved by the superpower system (Table 48) the percentages given in columns 39 and 41, "For power" and "For heating and process work," are to be construed not as percentages for the whole industry but as percentages for only that part for which purchased energy might have been supplied. These percentages were obtained from the analyses made by the authorities consulted.

Column 33 shows the power that might have been supplied economically to each industry by a superpower system. In determining this item the groups that use waste gases for fuel, that use waste-heat boilers, and that have water power were omitted. In all but a very few industries it was found to be more economical for plants of less than 200 horsepower to purchase all the energy they require, regardless of their requirements for heat. Almost the same is true

for plants of 201 to 500 horsepower. It is only in plants that are larger than 500 horsepower and that have some special requirements for heat that the generation of power can be justified. Even in these plants the power supply and demand can not be completely balanced, and central-station connections should be available for taking up irregularities.

SECONDARY SAVINGS.

In this analysis the only fuel saving credited to the purchase of electrical energy is the direct saving in the production of power. Experience has shown that in plants using purchased power much of the fuel formerly used for process heat can be saved through the simplification of the heating arrangements by the elimination of power production. Further, it was assumed in the analysis that much prime-mover power would be retained, owing to the use of waste-heat boilers and strict modernization of power-producing equipment. Such improvements would undoubtedly also result in an improvement in the heating arrangements similar to that found in an establishment purchasing electrical energy.

WATERWORKS.

The accompanying tables do not include the mechanical power-supply equipment or fuel used by waterworks, because these plants are usually considered in a different class from industries. A survey of the waterworks in the superpower zone shows that they used 260,000 long tons of anthracite and 260,000 short tons of bituminous coal in 1919. To replace this coal would require 340,000,000 kilowatt-hours of energy, the generation of which would require 340,000 tons of coal, at 2 pounds of coal per kilowatt-hour at the motor leads; this indicates a saving of the equivalent of 154,000 tons of bituminous coal. The possible load due to waterworks has not been included in any figure of this analysis.

COMMENTS ON SPECIAL INDUSTRIES.

The industry using the largest amount of coal is anthracite mining, and in this industry a coal saving of more than 75 per cent could be made if the mines were supplied from an efficient central electric power system. The present large consumption may be accounted for by the use of inefficient prime movers, long steam lines, inefficient pumps, and improper boiler and furnace design for burning the coal.

Many industries could save coal by the use of waste-heat boilers. Probably the greatest saving by this means could be made in the cement industry. It is estimated that if waste-heat boilers had been in use in all the cement plants in the superpower zone in 1919, 540,000 tons of coal would have been saved.

There are many blast furnaces in the superpower zone which are isolated from any steel plants or rolling mills, and approximately half their gases are wasted. These gases would produce sufficient heat for boilers to generate 500,000,000 kilowatt-hours a year.

In certain plants the low-pressure steam requirements greatly exceed the power requirements, and there is no reason why such plants should not generate by-product power and sell it to the electrical distributing companies.

ENERGY REQUIRED BY LOAD CENTERS.

Table 49 gives the electric energy in kilowatt-hours that might have been supplied by a superpower system in 1919 to replace the energy produced by prime movers in isolated plants. The factors for energy requirements obtained from the analysis summarized in Table 48 were applied to the detailed data for each industry in the Bureau of the Census, and the results summarized by load centers are given in Table 49.

TABLE 49.—*Electric energy, in kilowatt-hours, that might have been supplied by a superpower system in 1919 to replace the energy produced by prime movers in isolated plants.*

Load center.	Total energy at motors.	Portion of energy for anthracite mines at motors.
Boston	206,000,000	.....
Lowell	193,500,000	.....
Providence	536,000,000	.....
Worcester	130,000,000	.....
Northampton	105,500,000	.....
Hartford	103,000,000	.....
New Haven	277,000,000	.....
Albany	155,000,000	.....
Utica	59,800,000	.....
New York	460,000,000	.....
Newark	625,000,000	.....
Hudson	40,000,000	.....
Wilkes-Barre	860,700,000	785,200,000
Allentown	162,000,000	.....
Pottsville	495,500,000	415,470,000
Baltimore	125,000,000	.....
Harrisburg	230,800,000	14,780,000
Philadelphia	698,000,000	.....
Trenton	121,000,000	.....
Washington	40,000,000	.....
	5,623,800,000	1,215,450,000

PREDICTION OF FUTURE LOAD.

Figure 17 shows the past and predicted future industrial mechanical power-supply equipment. The past has been plotted from Census data and the future from the past and the opinion of several authorities on industrial development in the zone. It is shown in Table 48 that on the average 1.18 horsepower of motors is required to replace 1 horsepower of prime movers. The increase in recent years of motors operated by purchased energy has therefore affected the aggregate horsepower, giving the curve an increased slope. This has been considered in predicting the 1930 value, which shows an increase in the aggregate horsepower of 33 per cent from 1919. If the ratio of motors operated by purchased energy to aggregate horsepower remained as in 1919 the increase in aggregate horsepower in 1930 would be only 20 per cent.

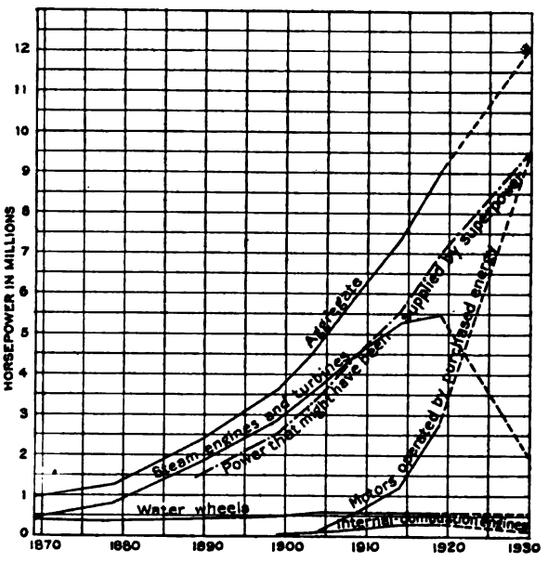


FIGURE 17.—Past and predicted future mechanical power-supply equipment used by industries in superpower zone, 1870-1930.

The curve of horsepower that might have been supplied by superpower as drawn in figure 17 is based on the analysis in Table 48 for 1919. As in that year 4,008,200 horsepower of prime movers would have been replaced by 4,703,000 horsepower of motors, it has been necessary to consider the ratios discussed in the preceding paragraph in plotting this curve. When "saturation" is reached in 1930 these considerations are eliminated; prior to that time the form of the curve is correct, but exact values have been adjusted in consideration of the actual horsepower of motors operated by purchased energy.

COST OF INDUSTRIAL POWER.

Figures 18 and 19 show the comparative cost of power generated in isolated condensing plants of capacities up to 5,000 kilowatts, operating at four load factors, and of purchased power for the same capacities. For the same load factor the curve of the cost of purchased power

is considerably below the cost of generated power. As these curves represent condensing plants, all noncondensing plants, where the exhaust steam is not utilized in manufacturing, would realize an even greater saving by the purchase of power.

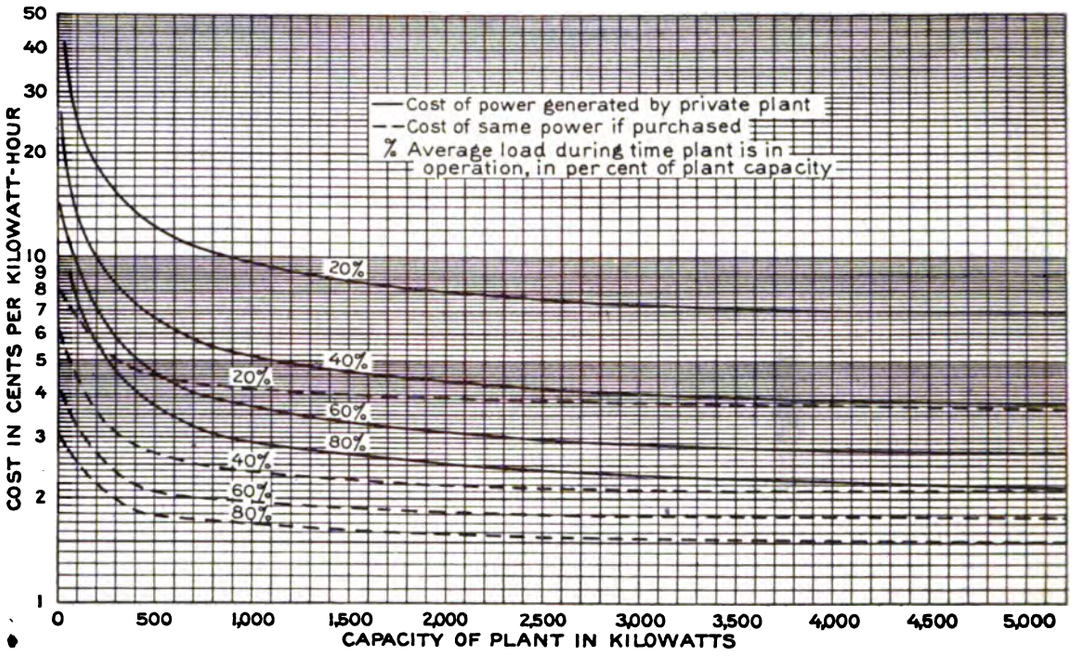


FIGURE 18.—Cost of electric power for industrial plants operating one shift daily. Based on prices and central-station rates prevailing in July, 1919. Coal figured at $5.18 per short ton delivered. Fixed charges, 16 per cent.

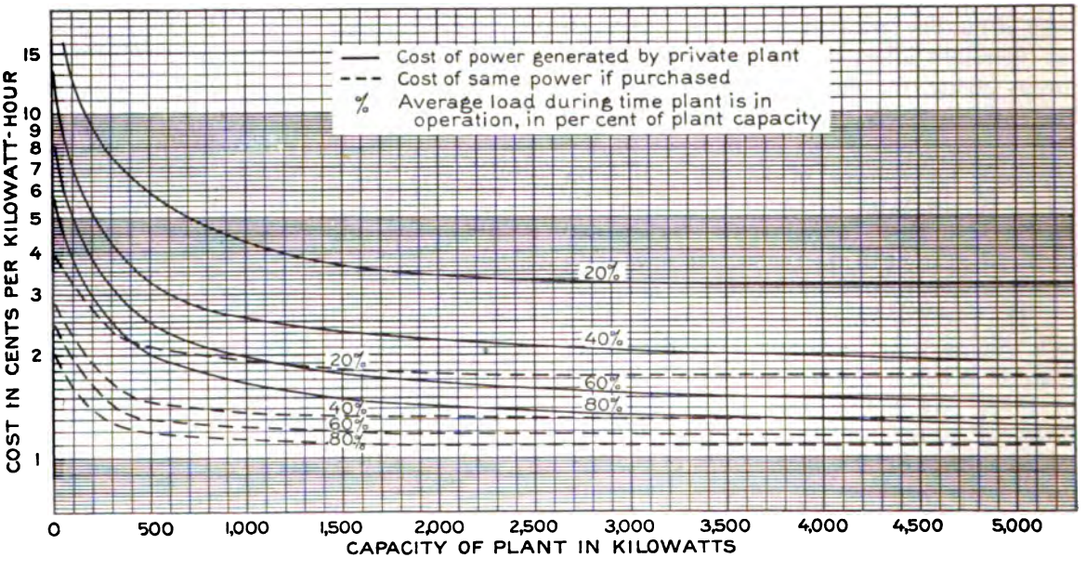


FIGURE 19.—Cost of electric power for industrial plants operating three shifts daily. Based on prices and central-station rates prevailing in July, 1919. Coal figured at $5.18 per short ton delivered. Fixed charges, 16 per cent.

ISOLATED PLANTS.

The cost of power shown for isolated plants includes all labor, fuel, and fixed charges. Labor rates are those of 1919. Fuel was charged at $5.18 per short ton delivered. Fixed charges, including interest, depreciation, taxes, and insurance, were taken as 16 per cent of

the investment cost as of 1919. The isolated plants were assumed to be designed in accordance with the best modern practice.

CENTRAL STATIONS.

The central-station rates shown on the curves are the average rates in force in 1919 for several electric utilities that used coal-produced energy exclusively and that supply approximately 400,000,000 kilowatt-hours yearly for industrial power at these rates. The rates are adjusted to coal at $5.18 per short ton delivered. At the present time these rates are typical of the large central stations only and not of the smaller companies, which are prevented by limitations of generating capacity from soliciting large power loads. These limitations would, however, be removed by the development of a complete unified system of electric supply.

SAVING IN COST OF POWER TO INDUSTRIES.

In Table 50 are given estimates showing the saving in cost of power to the industries possible by a change from the several types of power-supply equipment actually used in 1919 to the maximum economical use of purchased electrical energy. The costs of power have been taken from figure 18, the data being applied in detail to each type and average size of plant, and the estimates therefore show the difference between average best isolated-plant practice and central-station service. Savings are also shown for 1930 on the same basis as for 1919. A fixed charge of 16 per cent per annum has been made against electrification, based on the cost of motors at $35 per horsepower installed. It is to be noted that in either 1919 or 1930, when the maximum purchase of electrical energy is considered, the aggregate horsepower is greater, owing to the ratio of motor to engine horsepower, as explained in connection with figure 17. The figures in the last two columns of the table are rounded to represent the nearest $10,000,000.

TABLE 50.—*Possible saving in annual cost of industrial power through maximum economical use of purchased electrical energy, 1919 and 1930.*

1919.			
Actual proportion of power-supply equipment, 9,069,000 horsepower (average cost, $55 per horsepower-year)			$500,000,000
With maximum purchase of electrical energy:			
9,764,000 horsepower (average cost, $32 per horsepower-year)		$310,000,000	
	Horsepower.		
Motors required	4,703,000		
Motors now installed and available (21 per cent)	990,000		
New motors required	3,713,000		
Cost of motors installed, $130,000,000.			
Motor fixed charge, at 16 per cent		20,000,000	
			330,000,000
Possible saving			170,000,000
1930.			
Arrested development, based on a supply of industrial power by equipment in the same proportion as was actually used in 1919, 11,100,000 horsepower (average cost, $55 per horsepower-year)			$610,000,000
With maximum purchase of electrical energy:			
12,150,000 horsepower (average cost, $32 per horsepower-year)		$390,000,000	
	Horsepower.		
Motors required	6,700,000		
Motors now installed and available (21 per cent)	1,400,000		
New motors required	5,300,000		
Cost of motors installed, $185,000,000.			
Motor fixed charge, at 16 per cent		30,000,000	
			420,000,000
Possible saving			190,000,000

APPENDIX E.

PERFORMANCE AND COST OF THE SUPERPOWER SYSTEM.

By HENRY FLOOD, jr., A. R. WELLWOOD, and others of the engineering staff.

GENERAL CONDITIONS.

The accompanying tables and diagrams show the investment cost and the cost of power delivered by a superpower system to the load centers in 1919, in 1925, and in 1930. St. Lawrence and Niagara power will probably not be available until after 1930, but the effect of St. Lawrence power on the Eastern New England, Western New England, and Mohawk-Hudson divisions and that of Niagara power on the Metropolitan division are shown for 1932.

The cost of delivering power from a superpower system in 1930 if all the new power plants were of the steam-electric type is mentioned in order to justify the construction of both steam-electric and hydro-electric plants as proposed.

The figures given for cost of superpower operation, including those for 1919, are of course hypothetical; the figures for independent operation in 1919, where given, represent actual cost.

DEMAND AND ENERGY.

Table 51 shows the estimated demand and energy for the superpower system in 1919, 1925, and 1930. These estimates are based on the rate of growth of the utilities, the industries, and the railroads within the zone.

The figures in the first two columns in this table show the peak demand for power and the energy used during the year 1919 that could have been economically supplied by a superpower system. The figures in the second column include, first, the energy actually supplied by electric public-utility companies as reported by them; second, the energy now generated and used by isolated plants of industries that might have obtained it more economically from a superpower system, as determined by a method stated in detail in Appendix D (p. 143); third, the energy required for the heavy-traction load, which includes that of the railroads which can be economically electrified.

The figures showing the demand in 1919 were derived from the load factor of the energy actually supplied to the load centers in that year. The industrial and railroad loads that were added naturally tended to raise the load factor, but in order to be conservative the electric-utility load factor used was that for 1919.

TABLE 51.—*Demand and energy requirements for superpower zone.*

Geographic division and load center.	1919		1925		1930	
	Demand (thousands of kilowatts).	Energy (millions of kilowatt-hours).	Demand (thousands of kilowatts).	Energy (millions of kilowatt-hours).	Demand (thousands of kilowatts).	Energy (millions of kilowatt-hours).
Eastern New England:						
Boston	296.0	1,069.7	382	1,439	492	1,886
Lowell	107.6	390.5	36	136	45	173
Newburyport	.....	.....	54	203	67	257
Brockton	.....	.....	27	102	41	155
Providence	291.0	1,019.8	161	608	246	939
New Bedford	.....	.....	71	266	108	414
Worcester	148.1	535.9	187	704	244	931
	842.7	3,015.9	918	3,458	1,243	4,755

TABLE 51.—*Demand and energy requirements for superpower zone*—Continued.

Geographic division and load center.	1919		1925		1930	
	Demand (thousands of kilowatts).	Energy (millions of kilowatt-hours).	Demand (thousands of kilowatts).	Energy (millions of kilowatt-hours).	Demand (thousands of kilowatts).	Energy (millions of kilowatt-hours).
Western New England:						
Bridgeport	.....	.....	115	428	146	555
New Haven	244.0	869.8	64	239	81	308
Norwich	.....	.....	39	144	49	184
Waterbury	.....	.....	44	165	57	218
Hartford	75.9	270.6	80	297	103	392
Northampton	148.5	530.4	136	507	173	657
Pittsfield	.....	.....	35	129	43	163
	468.4	1,670.8	513	1,909	652	2,477
Mohawk-Hudson:						
Schenectady	201.0	811.9	233	973	300	1,263
Utica	58.6	238.5	92	383	162	680
Poughkeepsie	62.1	262.5	56	356	83	374
Port Jervis	.....	.....	34	155	46	209
	321.7	1,312.9	415	1,767	591	2,526
Metropolitan:						
New York	923.0	3,595.5	1,270	5,066	1,570	6,393
Paterson	.....	.....	55	219	66	271
Newark	513.0	1,994.5	360	1,438	461	1,878
New Brunswick	.....	.....	45	180	59	239
	1,436.0	5,590.0	1,730	6,903	2,156	8,781
Anthracite:						
Scranton	.....	.....	120	569	168	771
Wilkes-Barre	346.2	1,592.9	145	687	218	1,000
Hazleton	.....	.....	156	737	229	1,051
Allentown	150.0	689.4	58	276	78	359
Pottsville	157.2	723.0	70	331	92	425
	653.4	3,005.3	549	2,600	785	3,606
Southern:						
Trenton	91.3	376.2	83	342	99	426
Philadelphia	534.0	2,202.7	706	2,983	1,040	4,459
Reading	.....	.....	106	448	144	619
Harrisburg	212.2	875.7	161	681	219	941
Wilmington	.....	.....	46	196	65	282
Baltimore	223.1	921.7	291	1,229	336	1,447
Washington	71.2	292.9	84	354	92	393
	1,131.8	4,669.2	1,477	6,233	1,995	8,567
Superpower zone	4,854.0	19,264.1	5,602	22,870	7,422	30,712

Figure 20 shows the distribution of load in the superpower zone for 1925 and 1930 and is comparable to figure 1 (p. 33), showing the distribution of the electric-utility load in 1919.

Figure 21 shows the load in 1919 and 1930 for each center compared with that of New York, which has been taken at 100 per cent. This chart shows the decentralization that should occur between those years through the agency of a superpower system. The electrification of heavy-traction railroads and of isolated industrial plants will be effective in relieving the congestion of load at the larger centers. For 1919 only 20 load centers are designated for the electric-utility load; for 1925 and 1930 the number of centers is increased to 34. For these later years the heavy-traction railroad load is added to that of the electric utilities, thus making it desirable and economical to tap the transmission system at a larger number of points. However, from the cost of substations given in Appendix H it is evident that it will not be economical to tap the transmission system for a load of less than 20,000 kilowatts.

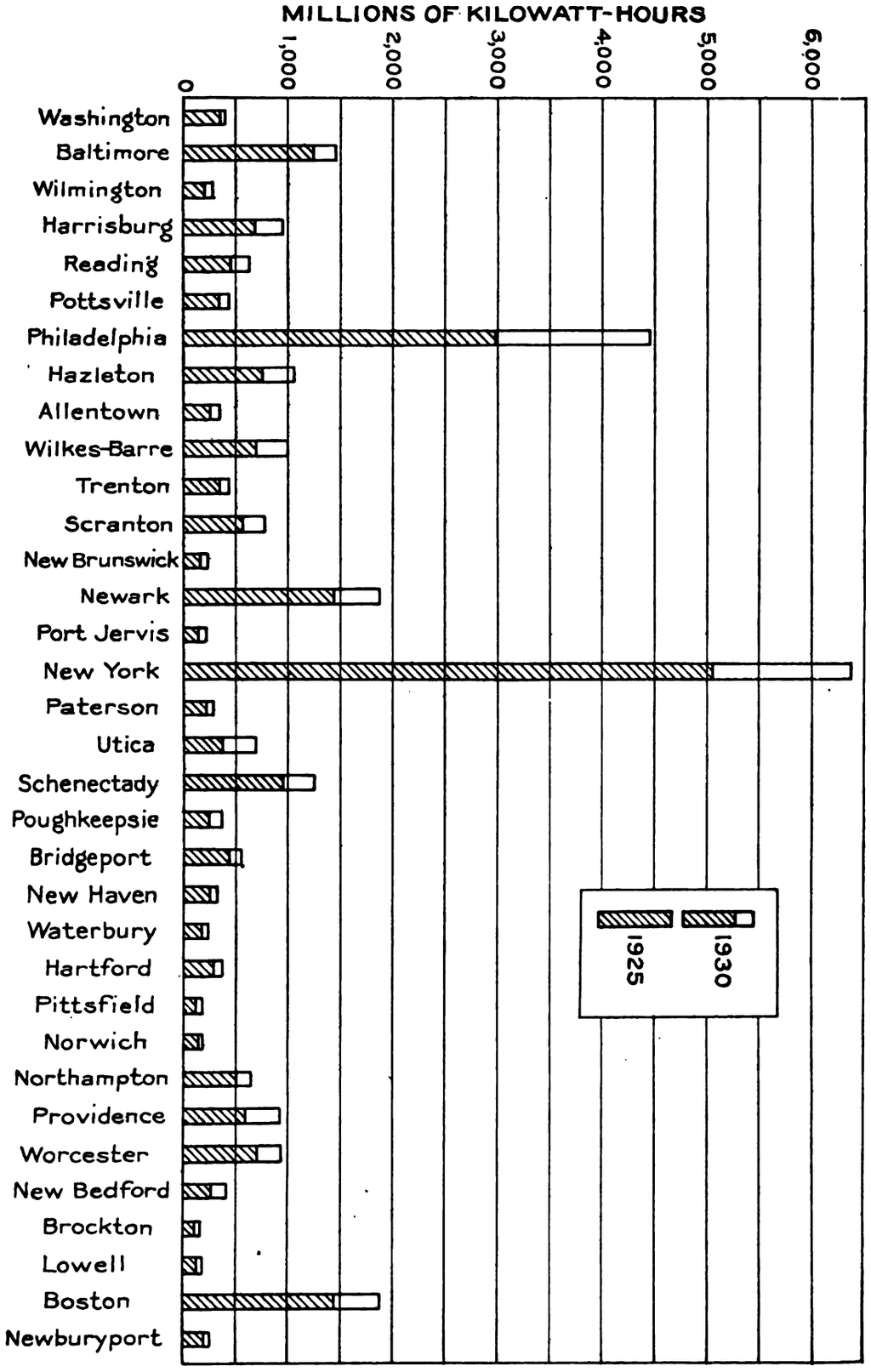


FIGURE 20.—Distribution of load among load centers of the superpower system for 1925 and 1930.

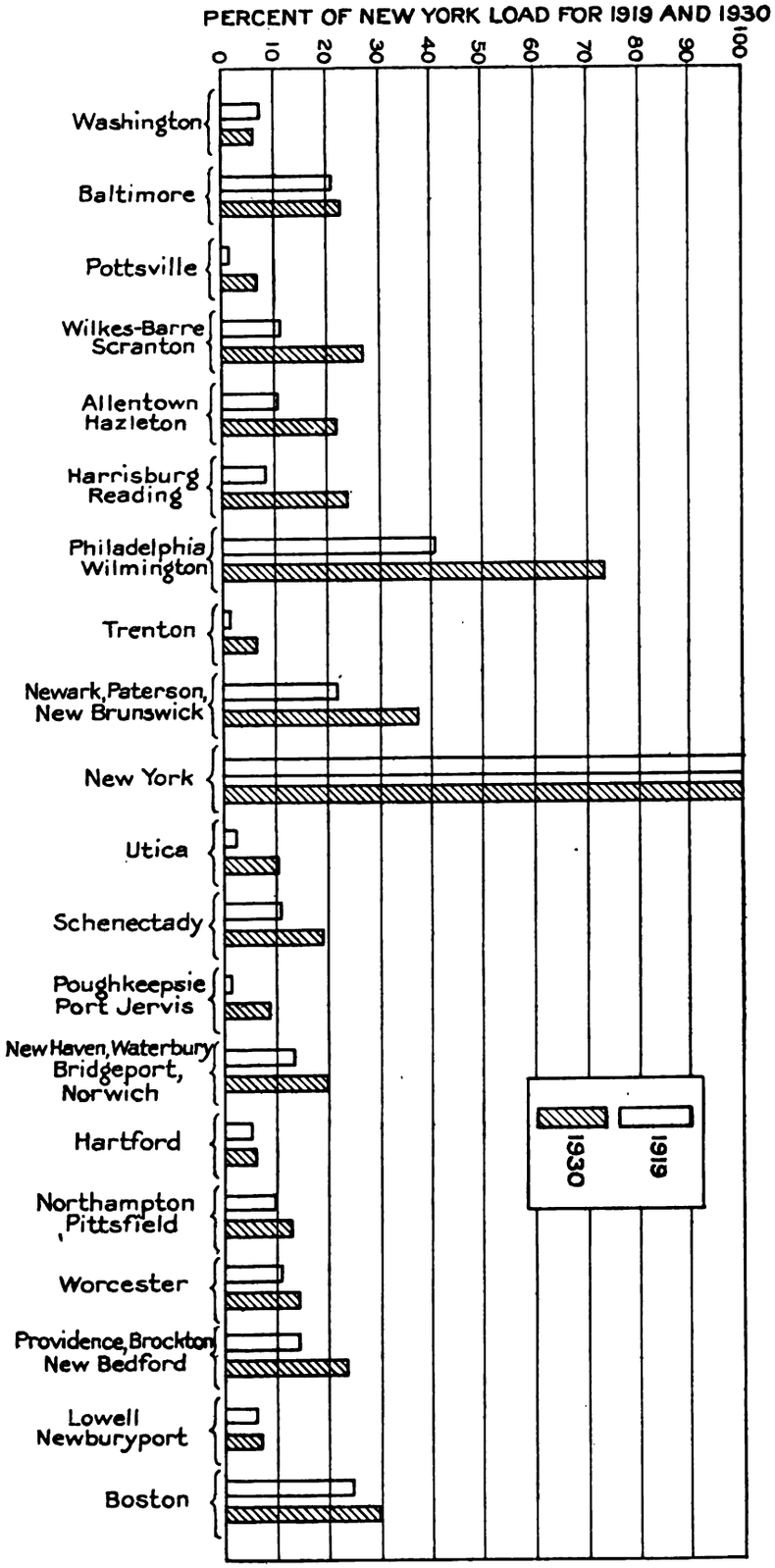


FIGURE 21.—Load at the several load centers in 1919 and 1930, in percentage of load at New York. This diagram shows decentralization of the load through the relatively large growth of heavy-traction railroad and industrial loads. The 20 load centers for 1919 have been increased to 24 for 1930. The first name in each group is the original load center; the others are the additional centers for 1930. The district represented by each group is the same for both years.

FREQUENCY.

The adoption of a standard frequency for the entire country would afford unquestionable advantages. The two frequencies 60 and 25 cycles have become well established throughout the superpower zone. Table 52 is a summary of the energy generated at different frequencies in each geographic division during 1919.

TABLE 52.—*Percentages of energy generated at different frequencies for electric public utilities in the superpower zone in 1919.*

Geographic division.	Demand (thousands of kilowatts).	Output (millions of kilowatt-hours).	Percentage of output generated at different frequencies.		
			25 cycles.	60 cycles.	Other frequencies.
Eastern New England	572.82	1,772.41	19.8	70.0	10.2
Western New England	314.13	921.99	18.8	73.3	7.9
Mohawk	135.87	438.16	8.4	24.2	67.4
Metropolitan	1,165.00	3,866.67	71.6	27.8	.6
Hudson	21.50	60.48	.0	98.1	1.9
Anthracite	185.08	743.06	30.2	66.9	2.9
Southern	660.69	2,498.36	51.1	44.8	4.1
	3,055.09	10,301.13	47.0	46.2	6.8

Table 53 shows the percentages of energy generated at different frequencies in the five most densely populated load centers in the superpower zone—Boston, New York, Philadelphia, Baltimore, and Washington—and in the superpower zone exclusive of these five load centers.

TABLE 53.—*Percentages of energy generated at different frequencies at five principal load centers in superpower zone and in the remainder of the zone.*

	Demand (thousands of kilowatts).	Output (millions of kilowatt-hours).	Percentage of output generated at different frequencies.		
			25 cycles.	60 cycles.	Other frequencies.
Five principal load centers	1,782.76	6,102.54	68.2	28.0	3.8
Remainder of superpower zone	1,272.33	4,198.59	16.2	72.7	11.1

In New York City 84.6 per cent of the energy is generated at 25 cycles, in Baltimore 98.5 per cent, and in Washington 99 per cent. In all other parts of the superpower zone the principal frequency used is 60 cycles.

Table 54 shows the percentages of total capacity at different frequencies in the several geographic divisions of the superpower zone in 1919:

TABLE 54.—*Percentages of total capacity at different frequencies of steam-electric and hydroelectric plants generating electricity for use by electric public utilities in the superpower zone in 1919.*

Geographic division.	Capacity (thousands of kilowatts).			Percentage of total capacity at different frequencies.		
	Steam-electric.	Hydro-electric.	Total.	25 cycles.	60 cycles.	Other frequencies.
Eastern New England	815.7	96.0	911.7	21.8	67.7	10.5
Western New England	369.4	111.5	481.0	15.1	77.3	7.6
Mohawk	58.3	116.2	174.4	10.6	29.1	60.3
Metropolitan	1,629.8	8.7	1,638.5	70.1	27.9	2.0
Hudson	26.8	8.7	35.5	0	97.2	2.8
Anthracite	217.8	5.1	222.9	25.4	68.5	6.1
Southern	882.4	105.3	987.7	53.7	40.7	5.6
	4,000.2	451.5	4,451.7	45.5	46.8	7.7

Of the power-plant capacity in the zone 89.9 per cent is steam-electric and 10.1 per cent is hydroelectric.

The electric street railways are by far the principal users of 25-cycle energy, because 25-cycle rotary converters were developed before the use of 60-cycle converters became practicable.

Figure 22 shows the number of sales and the trend of sales of generating equipment in the superpower zone between 1914 and 1919 for the two frequencies mentioned. Similarly figure 23 shows the electric-utility output at the two frequencies for 1910 to 1919, inclusive. This figure indicates a decided trend toward 60 cycles, both in generator sales and in electric-utility output.

The generator, motor equipment, and transformers for a 60-cycle installation cost, respectively, about 10, 25, and 35 per cent less than those for a 25-cycle installation. A 300,000-kilowatt plant employing 60 cycles rather than 25 cycles would save in its generator equipment and in motors and transformers connected to its distribution system about $7,000,000. Incandescent lamps furnished with 60-cycle energy are free from the flickering that is incident to lower frequencies. On the other hand, for a steel mill, where slow-speed motors are used, and for street railways, where the energy is converted into direct current, the lower frequency can still be used with advantage where a large investment has already been made in equipment. Although 25 cycles has been the frequency used for two of the largest railroad electrifications in the zone it is evident that the trend is toward 60 cycles and that this frequency will eventually predominate. These two frequencies will be interconnected by means of frequency changers as rapidly as economic conditions justify their use.

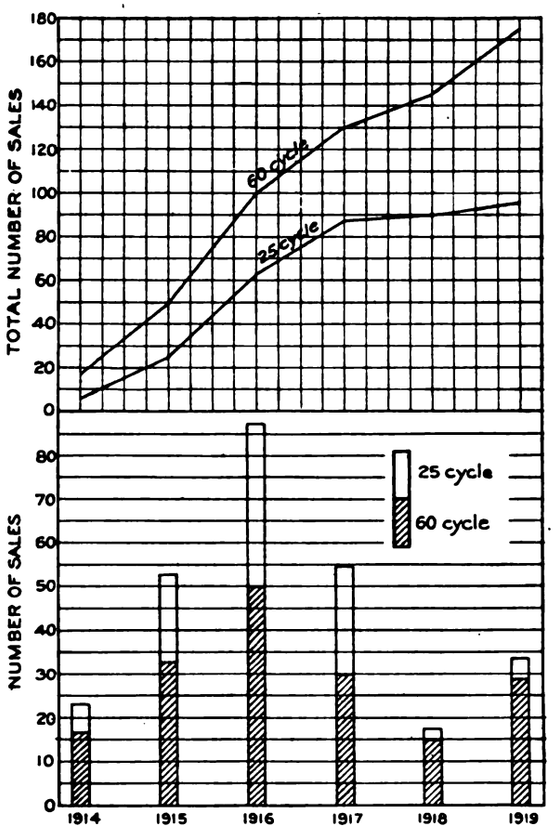


FIGURE 22.—Sales of 25-cycle and 60-cycle generators in the superpower zone, 1914-1919.

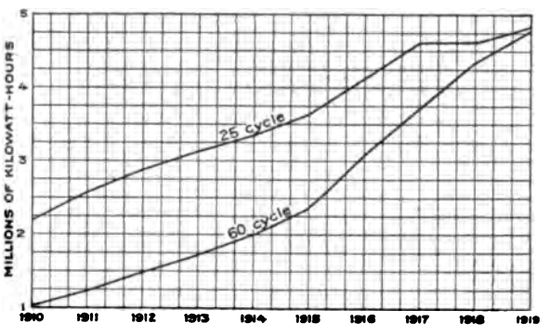


FIGURE 23.—Output of electric utilities in the superpower zone, 1910-1919.

For long-distance transmission there is a limit beyond which 60 cycles can not be used. A 60-cycle 220,000-volt line can be operated practically to a distance of 350 miles; lower frequencies may be necessary on longer lines.

It is clear that the superpower zone will eventually have an extensive network of interconnected transmission lines, and in order that this network may be established and operated at the least expense it is necessary to fix a standard frequency. The evidence assembled shows that this frequency should be 60 cycles.

ESTIMATED LOAD GROWTH.

Figure 24 shows graphically the past and estimated future load growth for the superpower zone for energy supplied to street railroads, electrified heavy-traction railroads, industries, and domestic consumers. This figure differs from Plate IV, in Appendix B, by the inclusion of the heavy-traction railroad load.

EFFECT OF DIVERSITY AND LOAD FACTOR.

Investigation was made of the diversity existing on November 25, 1919, the day of apparent maximum load for the superpower zone. Seasonal diversity, which is greater than daily diversity, was not taken into account.

There are three distinct diversities in the superpower zone—local diversity, or that which exists between the sum of the peaks of the individual electric public-utility companies as now operated and the peak that would be reached if they were interconnected at their respective load centers; regional diversity, or that which exists between the sum of the peaks of the individual load centers and the peak that would be reached in the entire superpower system if these load centers were interconnected; and total diversity, or that which exists between the sum of the peaks of the individual public-utility companies as now operated and the peak that would be reached in the superpower system if there were complete interconnection throughout the superpower zone.

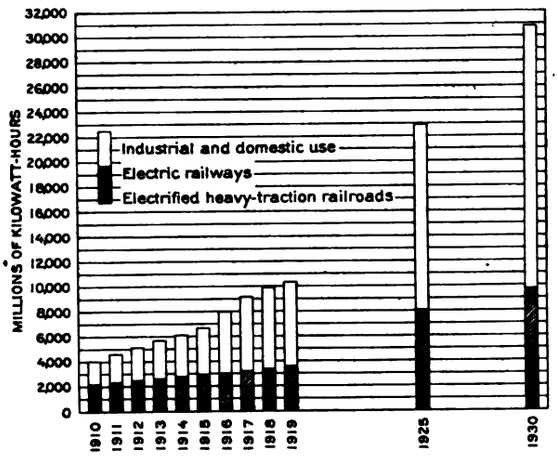


FIGURE 24.—Past and estimated future growth in load for superpower zone, 1910-1930.

The local diversity ranges from zero at Baltimore and Pottsville to 14.4 per cent at the New York load center. The comparatively high local diversity shown for New York on November 25 suggested the further investigation of this load center, where exceptional conditions exist. The following table shows the diversity that existed among the four largest utility companies in New York City on seven days in 1919 and three days in 1920:

TABLE 55.—*Diversity among four utility companies in New York on certain days.*

Date.	Total of noncoincident peak loads (thousands of kilowatts).	Coincident peak loads (thousands of kilowatts).	Time of coincident peaks.	Diversity factor.
July 22, 1919	563.0	511.1	9 a. m.	1.10
July 23, 1919	569.0	523.0	....do	1.09
July 24, 1919	529.8	508.6	....do	1.04
Nov. 25, 1919	779.4	695.0	5 p. m.	1.12
Dec. 16, 1919	745.5	688.5	....do	1.08
Dec. 17, 1919	763.6	725.1	....do	1.05
Dec. 18, 1919	783.4	741.0	....do	1.06
Dec. 14, 1920	788.3	728.1	....do	1.08
Dec. 15, 1920	800.9	739.4	....do	1.08
Dec. 16, 1920	821.9	779.8	....do	1.05

At certain load centers a large part of the local diversity has been absorbed through interconnection. Utilization of local diversity is not necessarily an attribute of the superpower system. It can be accomplished, as now, by the interconnection of the present electric-utility plants.

Regional diversity as applied to the superpower zone is in general so small as to be of theoretical rather than practical value. Partial regional diversity between the Anthracite division and the Metropolitan and Southern divisions is very marked and will become particularly evident with the growth of the Anthracite load by 1925 and 1930. In the Anthracite division the peak is controlled by the mining industry and occurs in the morning; there is a rapid falling off in load after 3 p. m. A combination of this load with the loads of the Metropolitan and Southern divisions will produce a great saving in power-plant cost over and above the cost of the transmission system necessary to effect the interconnection.

Table 56 shows the local diversity at each load center, the regional diversity between load centers, and the total diversity in 1919.

TABLE 56.—*Diversity in superpower zone, 1919.*

Geographic division and load center.	Noncoincident peak loads of utility companies (thousands of kilowatts).	Peak at load center if utility plants had been interconnected (thousands of kilowatts).	Local diversity factor.	Demand at load centers at time of superpower-zone peak (thousands of kilowatts).	Regional diversity factor.	Total diversity factor.
	A	B	C	D	E	F
Eastern New England:						
Boston	208.48	190.64	1.09	190.64		
Lowell	34.53	32.27	1.07	24.76		
Providence	132.10	121.07	1.09	121.07		
Worcester	91.25	85.51	1.07	85.51		
Western New England:						
Hartford	52.38	49.93	1.05	49.93		
New Haven	105.96	98.85	1.07	98.85		
Northampton	66.22	66.04	1.00	66.04		
Mohawk:						
Utica	22.83	22.34	1.02	19.76		
Albany	87.70	85.20	1.03	85.20		
Metropolitan:						
New York	863.78	755.25	1.14	755.25		
Newark	155.18	154.03	1.01	154.03		
Hudson:						
Poughkeepsie	11.96	11.50	1.04	10.37		
Anthracite:						
Pottsville	8.00	8.00	1.00	6.75		
Allentown	96.35	95.26	1.01	73.90		
Wilkes-Barre	50.01	45.85	1.09	44.89		
Southern:						
Trenton	5.15	4.90	1.05	3.99		
Harrisburg	51.84	51.03	1.02	51.03		
Philadelphia	297.24	286.72	1.04	286.72		
Baltimore	118.78	118.78	1.00	118.10		
Washington	55.20	54.22	1.02	52.96		
Superpower zone	2,514.94	2,337.39	.....	2,299.75	1.02	1.09

In this report diversity has been used only as an aid to determine the capacity that would have been required for a superpower system in 1919. The estimated capacity required for 1925 and 1930 is arrived at through a study of the trend of load factor for each of the individual load centers.

Figure 25 shows the trend of load factor in each geographic division of the superpower zone during the period 1910 to 1919, inclusive. The curve for the zone as a whole is extended to indicate estimated load factor on utility systems in 1930 (curve B). The steady improvement in load factor shown by these curves is due to three causes—interconnection of utility plants, increase of off-peak load, and growth of industrial demand. The greatest improvement in load factor is realized where the ratio of industrial load to lighting load is high. Where the industrial load is small compared with the lighting load, as in New York City, there is little opportunity for improvement in load factor.

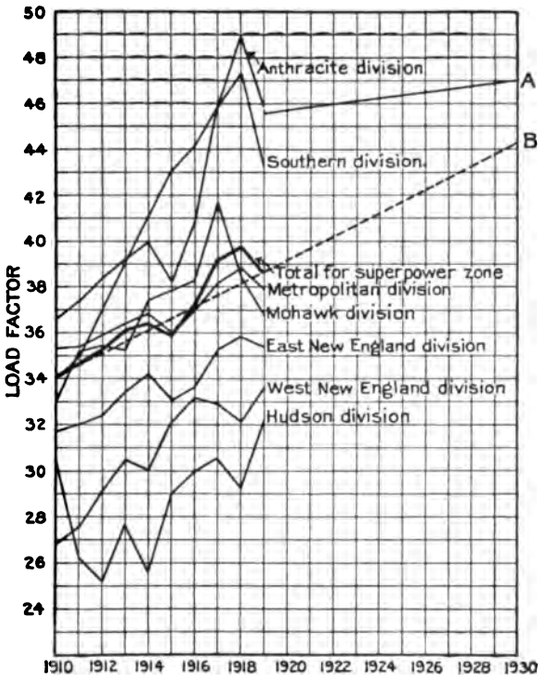


FIGURE 25.—Trend of load factor for superpower zone. A, Load factor inclusive of electrified heavy-traction railroads; B, load factor for electric utilities and street railroads.

The effect of the war in increasing the load factor in 1917 and 1918 by introducing overtime and night work in many of the industries is very apparent. In extending the curves to indicate future improvement in load factor this abnormal increase has been discounted.

Curve A in this figure shows the load factor assumed for superpower operation. This curve is determined by adding the heavy-traction railroad load to that of the street railroads and electric utilities, represented by curve B. With the expected growth of industrial and heavy-traction loads it would seem that the estimated load factor of 47 per cent for the entire superpower zone in 1930 is conservative.

PHYSICAL DATA.

PRODUCTION FACILITIES.

Table 60, giving the total power-plant capacity and output for the superpower system for 1919, 1925, and 1930, shows the following division of this capacity and output between steam-electric plants and hydroelectric plants:

TABLE 57.—*Capacity and output of steam-electric and hydroelectric plants, 1919, 1925, and 1930, in percentages.*

Year	Steam-electric.		Hydroelectric.	
	Capacity.	Output.	Capacity.	Output.
1919	81.8	78.2	18.2	21.8
1925	83.5	81.5	16.5	18.5
1930	81.5	79.2	18.5	20.8

The division of capacity and output between new power plants and present power plants retained for the superpower system is as follows:

TABLE 58.—*Capacity and output of new and retained plants, in percentages.*

Year.	New plants.			Existing plants retained.		
	Capacity.	Output.	Annual capacity factor.	Capacity.	Output.	Annual capacity factor.
1919	44.8	69.0	63.0	55.2	31.0	22.7
1925	49.8	74.0	64.6	50.2	26.0	22.8
1930	61.4	82.1	60.3	38.6	17.9	20.2

The higher efficiency under the superpower system is largely attained by operating the new power plants at high annual capacity factors and by using the older plants to carry peak load at low annual capacity factors.

TABLE 59.—*Weighted average capacity of the power plants of the superpower system, in kilowatts.*

	1925	1930
Hydroelectric plants retained	2,860	2,860
Steam-electric plants retained	44,600	44,600
Weighted average of old plants retained	14,300	14,300
New hydroelectric plants	36,100	30,000
New steam-electric plants	180,000	218,000
Weighted average of new plants	103,200	94,000
Weighted average of all plants	25,100	29,900

The average capacity of the steam-electric plants in operation in the electric utilities in 1919 was 10,000 kilowatts, and the average capacity of the steam-electric plants retained is 44,600 kilowatts, a gain made by eliminating the smaller and less efficient plants. The program of construction for new steam-electric plants shows an average capacity of plant in 1930 of more than twenty times that of the steam-electric plants serving electric public utilities in 1919.

TABLE 60.—*Power-plant capacity for the superpower system, 1919, 1925, and 1930.*

Geographic division.	Plant capacity (thousands of kilowatts).	Peak demand (thousands of kilowatts).	Plant reserve (thousands of kilowatts).	Output (millions of kilowatt-hours).	Capacity factor (per cent).
1919.					
Eastern New England:					
Present steam-electric plants	514.6	.....	.....	516.0	11.5
New steam-electric plants	360.0	.....	.....	2,366.0	75.0
	874.6	.....	.....	2,882.0	37.6
Present hydroelectric plants	96.0	.....	.....	269.0	32.0
New hydroelectric plants	.....	.....	.....	.....	.....
	96.0	.....	.....	269.0	32.0
All plants	970.6	842.7	127.8	3,151.0	37.0
Western New England:					
Present steam-electric plants	171.8	.....	.....	77.0	5.1
New steam-electric plants	270.0	.....	.....	1,091.0	46.0
	441.8	.....	.....	1,168.0	30.1
Present hydroelectric plants	111.5	.....	.....	340.0	34.8
New hydroelectric plants	50.0	.....	.....	230.0	52.5
	161.5	.....	.....	570.0	40.3
All plants	603.3	468.4	134.6	1,738.0	32.9

TABLE 60.—*Power-plant capacity for the superpower system, 1919, 1925, and 1930*—Continued.

Geographic division.	Plant capacity (thousands of kilowatts).	Peak demand (thousands of kilowatts).	Plant reserve (thousands of kilowatts).	Output (millions of kilowatt-hours).	Capacity factor (per cent).
1919—Continued.					
Mohawk-Hudson:					
Present steam-electric plants	45.7	.....	.....	20.0	5.0
New steam-electric plants	180.0	.....	.....	605.0	38.3
	225.7	.....	.....	625.0	31.6
Present hydroelectric plants	124.9	.....	.....	361.0	32.9
New hydroelectric plants	100.0	.....	.....	380.0	43.3
	224.9	.....	.....	741.0	37.6
All plants	450.6	321.7	129.3	1,366.0	34.5
Metropolitan:					
Present steam-electric plants	1,130.5	.....	.....	2,960.0	30.0
New steam-electric plants	[a] 240.0	.....	.....	[b] 2,088.0	51.3
	1,370.5	.....	.....	5,048.0	33.5
Present hydroelectric plants	8.7	.....	.....	22.0	28.8
New hydroelectric plants	183.0	.....	.....	850.0	53.0
	191.7	.....	.....	872.0	52.0
All plants	1,562.2	1,436.0	([c])	5,920.0	35.8
Anthracite:					
Present steam-electric plants	159.5	.....	.....	537.0	38.4
New steam-electric plants	[d] 450.0	.....	.....	[e] 1,950.0	75.0
	609.5	.....	.....	2,487.0	65.5
Present hydroelectric plants	5.1	.....	.....	16.0	35.9
New hydroelectric plants	.....	.....	.....	.....	.....
	5.1	.....	.....	16.0	35.9
All plants	614.6	653.4	([c])	2,503.0	65.3
Southern:					
Present steam-electric plants	654.5	.....	.....	579.0	10.1
New steam-electric plants	450.0	.....	.....	2,923.0	74.2
	1,104.5	.....	.....	3,502.0	36.2
Present hydroelectric plants	105.3	.....	.....	542.0	58.8
New hydroelectric plants	245.0	.....	.....	1,434.0	66.8
	350.3	.....	.....	1,976.0	64.3
All plants	1,454.8	1,131.8	([c])	5,478.0	42.9
Superpower zone:					
Present steam-electric plants	2,676.6	.....	.....	4,689.0	20.0
New steam-electric plants	1,950.0	.....	.....	11,023.0	64.5
	4,626.6	.....	.....	15,712.0	38.8
Present hydroelectric plants	451.5	.....	.....	1,550.0	39.2
New hydroelectric plants	578.0	.....	.....	2,894.0	57.0
	1,029.5	.....	.....	4,444.0	49.3
All plants	5,656.1	4,854.0	802.5	20,156.0	40.5

[a] Does not include the portion of the Pittston plant capacity chargeable to the Metropolitan division.
[b] Includes a portion of the output from the Pittston plant.
[c] Joint reserve for Metropolitan, Anthracite, and Southern divisions, 1919, is 410,800 kilowatts.
[d] Includes the total Pittston plant capacity.
[e] Is not the total output of the Pittston plant.

TABLE 60.—*Power-plant capacity for the superpower system, 1919, 1925, and 1930*—Continued.

Geographic division.	Plant capacity (thousands of kilowatts).	Peak demand (thousands of kilowatts).	Plant reserve (thousands of kilowatts).	Output (millions of kilowatt-hours).	Capacity factor (per cent).
1919—Continued.					
Superpower zone—Continued.					
Present plants retained	3,128.1	.....	.....	6,239.0	22.7
New plants proposed	2,528.0	.....	.....	13,917.0	62.9
Steam-electric ... per cent of total	81.8	.....	.....	78.2	.....
Hydroelectric ... do	18.2	.....	.....	21.8	.....
1925.					
Eastern New England:					
Present steam-electric plants	514.6	.....	.....	516.0	11.5
New steam-electric plants	450.0	.....	.....	2,811.0	71.2
	964.6	.....	.....	3,327.0	39.4
Present hydroelectric plants	96.0	.....	.....	269.0	32.0
New hydroelectric plants	.....	.....	.....	.....	.....
	96.0	.....	.....	269.0	32.0
All plants	1,060.6	918.0	142.5	3,596.0	38.7
Western New England:					
Present steam-electric plants	171.8	.....	.....	77.0	5.1
New steam-electric plants	300.0	.....	.....	1,223.0	46.5
	471.8	.....	.....	1,300.0	31.4
Present hydroelectric plants	111.5	.....	.....	340.0	34.8
New hydroelectric plants	50.0	.....	.....	230.0	52.5
	161.5	.....	.....	570.0	40.3
All plants	633.3	513.0	120.0	1,870.0	33.7
Mohawk-Hudson:					
Present steam-electric plants	45.7	.....	.....	20.0	5.0
New steam-electric plants	240.0	.....	.....	1,039.0	49.5
	285.7	.....	.....	1,059.0	49.5
Present hydroelectric plants	124.9	.....	.....	361.0	32.9
New hydroelectric plants	100.0	.....	.....	380.0	43.3
	224.9	.....	.....	741.0	37.6
All plants	510.6	415.0	96.0	1,800.0	40.2
Metropolitan:					
Present steam-electric plants	1,130.5	.....	.....	2,960.0	30.0
New steam-electric plants	[a] 390.0	.....	.....	[b] 3,508.0	67.0
	1,520.5	.....	.....	6,468.0	39.4
Present hydroelectric plants	8.7	.....	.....	22.0	28.8
New hydroelectric plants	183.0	.....	.....	850.0	53.0
	191.7	.....	.....	872.0	52.0
	1,712.2	1,730.0	([c])	7,340.0	40.8
Anthracite:					
Present steam-electric plants	159.5	.....	.....	537.0	38.4
New steam-electric plants	[d] 450.0	.....	.....	[e] 1,735.0	75.0
	609.5	.....	.....	2,272.0	65.5

[a] Does not include the portion of the Pittston plant capacity chargeable to the Metropolitan division.
[b] Includes a portion of the output from the Pittston plant.
[c] Joint reserve for Metropolitan, Anthracite, and Southern divisions, 1925, is 265,000 kilowatts.
[d] Includes the total Pittston plant capacity.
[e] Is not the total output of the Pittston plant.

TABLE 60.—*Power-plant capacity for the superpower system, 1919, 1925, and 1930*—Continued.

Geographic division.	Plant capacity (thousands of kilowatts).	Peak demand (thousands of kilowatts).	Plant reserve (thousands of kilowatts).	Output (millions of kilowatt-hours).	Capacity factor (per cent).
1925—Continued.					
Anthracite—Continued.					
Present hydroelectric plants	5.1	.....	.....	16.0	35.9
New hydroelectric plants	.....	.....	.....	.....	.....
	5.1	.....	.....	16.0	35.9
All plants	614.6	549.0	(a)	2,288.0	65.3
Southern:					
Present steam-electric plants	654.5	.....	.....	579.0	10.1
New steam-electric plants	690.0	.....	.....	4,365.0	72.2
	1,344.5	.....	.....	4,944.0	42.0
Present hydroelectric plants	105.3	.....	.....	542.0	58.8
New hydroelectric plants	245.0	.....	.....	1,434.0	66.8
	350.0	.....	.....	1,976.0	64.3
All plants	1,694.8	1,477.0	(a)	6,920.0	46.7
Superpower zone:					
Present steam-electric plants	2,676.6	.....	.....	4,689.0	20.0
New steam-electric plants	2,520.0	.....	.....	14,681.0	66.4
	5,196.6	.....	.....	19,370.0	42.5
Present hydroelectric plants	451.5	.....	.....	1,550.0	39.2
New hydroelectric plants	578.0	.....	.....	2,894.0	57.0
	1,029.5	.....	.....	4,444.0	49.3
All plants	6,226.1	5,602.0	624.5	23,814.0	43.7
Present plants retained	3,128.1	.....	.....	6,239.0	22.8
New plants proposed	3,098.0	.....	.....	17,575.0	64.6
Steam-electric ... per cent of total	83.5	.....	.....	81.5	.....
Hydroelectric ... do	16.5	.....	.....	18.5	.....
1930.					
Eastern New England:					
Present steam-electric plants	514.6	.....	.....	528.0	11.7
New steam-electric plants	810.0	.....	.....	4,148.0	58.3
	1,324.6	.....	.....	4,676.0	40.3
Present hydroelectric plants	96.0	.....	.....	269.0	32.0
New hydroelectric plants	.....	.....	.....	.....	.....
	96.0	.....	.....	269.0	32.0
All plants	1,420.6	124.3	177.5	4,945.0	39.6
Western New England:					
Present steam-electric plants	171.8	.....	.....	77.0	5.1
New steam-electric plants	390.0	.....	.....	1,237.0	36.2
	561.8	.....	.....	1,314.0	26.7
Present hydroelectric plants	111.5	.....	.....	340.0	34.8
New hydroelectric plants	165.0	.....	.....	760.0	52.5
	276.5	.....	.....	1,100.0	45.3
All plants	838.3	652.0	186.0	2,414.0	32.8
Mohawk-Hudson:					
Present steam-electric plants	45.7	.....	.....	20.0	5.0
New steam-electric plants	360.0	.....	.....	1,312.0	41.5
	405.7	.....	.....	1,332.0	37.4

a Joint reserve for Metropolitan, Anthracite, and Southern divisions, 1925, is 265,000 kilowatts.

TABLE 60.—*Power-plant capacity for the superpower system, 1919, 1925, and 1930*—Continued.

Geographic division.	Plant capacity (thousands of kilowatts).	Peak demand (thousands of kilowatts).	Plant reserve (thousands of kilowatts).	Output (millions of kilowatt-hours).	Capacity factor (per cent).
1930—Continued.					
Mohawk-Hudson—Continued.					
Present hydroelectric plants	124.9	.....	.....	341.0	31.1
New hydroelectric plants	150.0	.....	.....	900.0	68.3
	274.9	.....	.....	1,241.0	51.7
All plants	680.6	591.0	90.0	2,573.0	43.0
Metropolitan:					
Present steam-electric plants	1,130.5	.....	.....	2,276.0	23.0
New steam-electric plants	[a] 750.0	.....	.....	[b] 5,812.0	67.5
	1,880.5	.....	.....	8,088.0	40.7
Present hydroelectric plants	8.7	.....	.....	22.0	28.8
New hydroelectric plants	350.0	.....	.....	1,240.0	40.5
	358.7	.....	.....	1,262.0	40.2
All plants	2,239.2	2,156.0	([c])	9,350.0	40.6
Anthracite:					
Present steam-electric plants	159.5	.....	.....	537.0	51.0
New steam-electric plants	[d] 600.0	.....	.....	[a] 2,571.0	75.0
	759.5	.....	.....	3,108.0	67.3
Present hydroe-ectric plants	5.1	.....	.....	16.0	35.9
New hydroelectric plants	.....	.....	.....	.....	.....
	5.1	.....	.....	16.0	35.9
All plants	764.6	785.0	([c])	3,124.0	67.1
Southern:					
Present steam-electric plants	654.5	.....	.....	579.0	10.1
New steam-electric plants	1,020.0	.....	.....	6,219.0	69.5
	1,674.5	.....	.....	6,798.0	46.2
Present hydroelectric plants	105.3	.....	.....	542.0	58.8
New hydroelectric plants	385.0	.....	.....	2,180.0	64.5
	490.3	.....	.....	2,722.0	63.4
All plants	2,164.8	1,995.0	([c])	9,520.0	50.0
Superpower zone:					
Present steam-electric plants	2,676.6	.....	.....	4,017.0	17.1
New steam-electric plants	3,930.0	.....	.....	21,299.0	61.8
	6,606.0	.....	.....	25,316.0	43.7
Present hydroelectric plants	451.5	.....	.....	1,530.0	38.6
New hydroelectric plants	1,050.0	.....	.....	5,080.0	55.2
	1,501.5	.....	.....	6,610.0	50.3
All plants	8,108.1	7,422.0	676.5	31,926.0	45.0
Present plans retained	3,128.1	.....	.....	5,547.0	20.2
New plants proposed	4,980.0	.....	.....	26,379.0	60.3
Steam-electric ..... per cent of total	81.5	.....	.....	79.2	.....
Hydroelectric ..... do	18.5	.....	.....	20.8	.....

[a] Does not include the portion of the Pittston plant capacity chargeable to the Metropolitan division.
[b] Includes a portion of the output from the Pittston plant.
[c] Joint reserve for Metropolitan, Anthracite, and Southern divisions 1930. is 233,000 kilowatts.
[d] Includes the total Pittston plant capacity.
[e] Is not the total output of the Pittston plant.

TRANSMISSION LINES.

Table 61 gives the mileage of the transmission lines required for the superpower system for 1919, 1925, and 1930.

Plates II and III (p. 14) show the proposed transmission lines for 1925 and 1930, respectively, and Plate III shows in addition proposed lines from the St. Lawrence and Niagara for 1932. These plates also show the approximate location for proposed new steam-electric and hydroelectric plants.

Reliable service is insured by the interconnecting network, as each principal load center is served by eight incoming lines, four from each direction, and a few favorably located load centers have even more.

TABLE 61.—*Transmission lines for superpower zone in 1919, 1925, and 1930, in miles.*

Year and geographic division.	220,000-volt.			110,000-volt.		
	Route.	Tower.	Circuit.	Route.	Tower.	Circuit.
1919.						
Eastern New England	0	0	0	207	207	414
Western New England	0	0	0	264	415	630
Mohawk-Hudson	0	0	0	237	317	634
Metropolitan	102	204	408	283	393	786
Anthracite	35	70	70	59	111	222
Southern	123	246	492	314	463	926
Superpower zone	260	520	970	1,364	1,806	3,612
1925.						
Eastern New England	0	0	0	262	262	524
Western New England	0	0	0	264	315	630
Mohawk-Hudson	0	0	0	237	317	634
Metropolitan	102	204	408	283	393	786
Anthracite	35	70	70	70	133	266
Southern	123	246	492	314	463	926
Superpower zone	260	520	970	1,430	1,883	3,766
1930.						
Eastern New England	0	0	0	262	262	524
Western New England	0	0	0	421	601	1,202
Mohawk-Hudson	0	0	0	262	418	836
Metropolitan	102	204	408	302	444	888
Anthracite	35	70	70	70	140	280
Southern	123	246	492	334	483	966
Superpower zone	260	520	970	1,651	2,348	4,696

SUBSTATIONS.

In Table 62 the transformer capacity does not include that installed in base-load steam-electric plants, and the synchronous-condenser capacity does not include the condenser effect of generators used as such, or of motor generator sets in the heavy-traction railroad substations.

TABLE 62.—*Substation capacity for the superpower system in 1919, 1925, and 1930, in thousands of kilovolt-amperes.*

Geographic division.	Transformers.		Synchronous condensers.	Frequency changers.
	220,000-volt primary.	110,000-volt primary.		
1919.				
Eastern New England	0	325	150	0
Western New England	0	125	105	0
Mohawk-Hudson	0	300	45	30
Metropolitan	800	483	135	0
Anthracite	125	425	90	0
Southern	200	495	165	0
Superpower zone	1,125	2,153	690	30
1925.				
Eastern New England	0	475	150	0
Western New England	0	375	105	0
Mohawk-Hudson	0	350	45	30
Metropolitan	850	633	135	0
Anthracite	50	500	90	0
Southern	300	595	165	0
Superpower zone	1,200	2,928	690	30
1930.				
Eastern New England	0	550	180	0
Western New England	0	590	135	0
Mohawk-Hudson	0	475	60	60
Metropolitan	1,050	935	180	0
Anthracite	75	675	150	0
Southern	325	935	195	0
Superpower zone	1,450	4,160	900	60

FUEL REQUIREMENT.

Table 65 gives the fuel requirement for the superpower system for 1919, 1925, and 1930. The estimated fuel saving by the superpower system to the electric public utilities is as follows:

TABLE 63.—*Fuel saving by superpower system to electric public utilities.*

	1919	1925	1930
Coal that would be required at 1919 fuel rate for electric power produced by steam ... short tons	24,600,000	29,600,000	39,700,000
Coal required for superpower operation ... do	14,103,000	16,591,000	20,551,000
Annual saving by superpower operation ... do	10,497,000	13,001,000	19,149,000
Average cost per ton of coal delivered to superpower system	$4.37	$5.25	$5.25
Value of fuel saving	$45,872,000	$68,200,000	$100,500,000

For independent operation the production of power by water has been taken at 2,100,000,000 kilowatt-hours for 1925 and 2,800,000,000 kilowatt-hours for 1930. These figures are based on growth of water power for the electric utilities indicated by data collected by the United States Bureau of the Census.

If in 1930 the superpower system were supplied with energy produced entirely from coal with the exception of that from existing hydroelectric plants the coal required would amount to 23,184,100 short tons, and the fuel saving would be 2,633,100 tons less than that effected by the proposed arrangement of superpower facilities for 1930.

TABLE 64.—*Fuel rate for superpower operation and rate under independent operation in 1919, in pounds of coal per kilowatt-hour generated.*

	1919	1925	1930
Superpower operation:			
New steam-electric plants	1.47	1.45	1.43
Retained steam-electric plants	2.54	2.54	2.64
Weighted average, steam-electric plants	1.80	1.71	1.62
Independent operation (1919 performance of electric utilities)	2.73	2.73	2.73

The average cost of fuel delivered to the new base-load steam-electric plants is lower than that for existing steam-electric plants because of the advantageous locations that can be selected for the new plants. (See Appendix F.) This difference is particularly marked in the comparison of the unit fuel cost for the electric utilities for 1919 (see p. 48) and that of the hypothetical superpower system for 1919, for which the cost of coal at the mine and the railroad freight rate have been assumed to be the same, the resulting cost to the utilities being $5.35 per short ton, whereas that to the superpower system is $4.37 per ton. For the same reason, despite the higher freight rates charged against coal to the superpower system for 1925 and 1930, the resulting unit cost to the superpower system is less than that to the electric utilities for 1919.

By the use of St. Lawrence power to the extent of 600,000 kilowatts at a load factor of 80 per cent in the Eastern New England, Western New England, and Mohawk-Hudson divisions in 1932 the annual coal requirement will be 2,234,000 tons less than the quantity which would be used were this amount of power generated by new steam-electric plants. By the use of Niagara power to the extent of 300,000 kilowatts at a load factor of 80 per cent in the Metropolitan division in 1932 the annual coal requirement will be 1,204,000 tons less than the quantity which would be used were this amount of power generated by new steam-electric plants.

TABLE 65.—*Fuel requirements for superpower system for 1919, 1925, and 1930.*

Geographic division.	Coal per kilowatt-year of capacity (short tons).	Total quantity of coal per year (thousands of short tons).	Cost per short ton delivered.	Total annual cost.	Coal per kilowatt-hour (pounds).
1919.					
Eastern New England:					
Present plants	1.31	673.2	$6.15	$4,132,000	2.61
New plants	3.92	1,412.0	6.10	8,620,000	1.20
	2.39	2,085.2	6.11	12,752,000	1.44
Western New England:					
Present plants	.84	144.8	5.88	851,000	3.76
New plants	2.70	729.0	5.67	4,130,000	1.33
	1.97	873.8	5.70	4,981,000	1.50
Mohawk-Hudson:					
Present plants	1.12	51.2	5.32	272,000	5.12
New plants	2.28	410.0	5.32	2,180,000	1.35
	2.04	461.2	5.32	2,452,000	1.47
Metropolitan:					
Present plants	2.80	3,170	5.22	16,550,000	2.14
New plants	2.99	[a] 1,625	5.22	5,878,000	1.33
	2.84	4,795	5.22	22,428,000	1.93
Anthracite:					
Present plants	6.80	1,085	2.53	2,752,000	4.04
New plants	5.92	[a] 1,759.0	2.35	4,135,000	1.80
	6.17	2,844.0	2.41	6,887,000	2.15

[a] Includes a portion of the coal burned in the Pittston plant.

TABLE 65.—*Fuel requirements for superpower system for 1919, 1925, and 1930*—Continued.

Geographic division.	Coal per kilowatt-year of capacity (short tons).	Total quantity of coal per year (thousands of short tons).	Cost per short ton delivered.	Total annual cost.	Coal per kilowatt-hour (pounds).
1919—Continued.					
Southern:					
Present plants	1.29	845.8	$5.05	$4,270,000	2.93
New plants	4.88	2,198.0	3.66	8,045,000	1.50
	2.76	3,043.8	4.05	12,315,000	1.73
Superpower zone:					
Present plants	2.23	5,969.8	4.84	28,827,000	2.54
New plants	4.16	8,133.0	4.06	32,988,000	1.47
	3.05	14,102.8	4.37	61,815,000	1.80
1925.					
Eastern New England:					
Present plants	1.29	665.3	7.40	4,928,300	2.58
New plants	3.74	1,679.0	7.42	12,435,000	1.19
	2.44	2,344.3	7.40	17,363,300	1.41
Western New England:					
Present plants	.84	144.8	7.10	1,028,900	3.76
New plants	2.72	816.0	6.86	5,600,000	1.33
	2.04	960.8	6.90	6,628,900	1.48
Mohawk-Hudson:					
Present plants	1.12	51.2	6.33	324,000	5.14
New plants	2.88	692.0	6.33	4,380,000	1.33
	2.60	743.2	6.33	4,704,000	1.40
Metropolitan:					
Present plants	2.80	3,170.0	6.25	19,800,000	2.14
New plants	3.84	[a] 2,598.0	6.25	12,190,000	1.32
	3.06	5,768.0	6.25	31,990,000	1.68
Anthracite:					
Present plants	6.80	1,085.0	2.81	3,046,000	4.04
New plants	5.92	[a] 1,565.0	2.57	4,025,000	1.80
	6.17	2,650.0	2.65	7,071,000	2.15
Southern:					
Present plants	1.29	845.8	5.89	4,979,000	2.93
New plants	4.75	3,279.0	4.42	14,480,000	1.50
	3.06	4,124.8	4.72	19,459,000	1.67
Superpower zone:					
Present plants	2.23	5,962.1	5.72	34,106,200	2.54
New plants	4.23	10,629.0	5.00	53,110,000	1.45
	3.20	16,591.1	5.25	87,216,200	1.71
1930.					
Eastern New England:					
Present plants	1.30	673.2	7.43	4,995,000	2.55
New plants	3.10	2,512.0	7.42	18,610,000	1.21
	2.41	3,185.2	7.42	23,605,000	1.37
Western New England:					
Present plants	.84	144.8	7.10	1,029,000	3.76
New plants	2.17	846.0	6.87	5,810,000	1.37
	1.76	990.8	6.90	6,839,000	1.51

[a] Includes a portion of the coal burned in the Pittston plant.

TABLE 65.—*Fuel requirements for superpower system for 1919, 1925, and 1930*—Continued.

Geographic division.	Coal per kilowatt-year of capacity (short tons).	Total quantity of coal per year (thousands of short tons).	Cost per short ton delivered.	Total annual cost.	Coal per kilowatt-hour (pounds).
1930—Continued.					
Mohawk-Hudson:					
Present plants	1.12	51.2	$6.33	$324,000	5.14
New plants	2.47	888.0	6.33	5,620,000	1.35
	2.31	939.2	6.33	5,944,000	1.41
Metropolitan:					
Present plants	2.23	2,522.0	6.25	15,763,000	2.22
New plants	3.86	[a] 4,131.0	6.25	21,300,000	1.31
	2.88	6,653.	6.25	37,063,000	1.61
Anthracite:					
Present plants	6.80	1, 85.0	2.81	3,046,000	4.04
New plants	5.92	[a] 2,316.0	2.57	5,948,000	1.80
	6.10	3,401.0	2.63	8,994,000	2.07
Southern:					
Present plants	1.29	845.8	5.89	4,979,000	2.93
New plants	4.44	4,536.0	4.57	20,670,000	1.46
	3.21	5,381.8	4.77	25,649,000	1.59
Superpower zone:					
Present plants	1.98	5,322.0	5.67	30,136,000	2.64
New plants	3.88	15,229.0	5.11	77,958,000	1.43
	3.11	20,551.0	5.25	108,094,000	1.62

[a] Includes a portion of the coal burned in the Pittston plant.

INVESTMENT COST.

The total investment cost for the facilities of the superpower system for 1919, 1925, and 1930 is given in Table 68. The unit cost is shown below; the figures for the retained plants represent reproduction cost in midyear of 1919.

TABLE 66.—*Unit investment cost of superpower system per kilowatt of installed plant capacity.*

	1919	1925	1930
New steam-electric plants	$112.00	$110.60	$109.50
New hydroelectric plants	151.90	151.90	151.30
Average, new plants	121.10	118.40	118.25
Retained steam-electric plants	123.00	123.00	123.00
Retained hydroelectric plants	193.60	193.60	193.60
Average, retained plants	133.00	133.00	133.00
Average, all plants	127.80	125.80	125.00

The greater unit cost of the plants retained is the result of their smaller individual capacity. The new hydroelectric plants for the superpower system are to be located only at the most economical sites and constructed largely to carry peak loads, and therefore they show a lower unit investment cost.

TABLE 67.—*Unit investment cost per kilowatt of demand for all facilities of superpower system.*

	1919	1925	1930
Power plants	$149.00	$140.00	$136.80
Transmission system	16.00	15.40	14.05
	165.00	155.40	150.85

The reproduction cost of the power plants of the electric utilities in 1919 was $598,277,000, or $196 per kilowatt of demand.

The new money required for the superpower project is $453,143,000 by 1925 and $693,218,000 by 1930, thus making it necessary to raise about $90,600,000 annually for the first five years and $48,000,000 annually for the succeeding five-year period. The early installation of the transmission network is responsible for the higher annual requirement for the first five years. This expenditure, however, is justified by the saving that will result through interconnection.

If the increase in demand to 1930 were provided for by independent systems such as were in existence in 1919, a total of about $856,000,000 would have to be expended, requiring financing to the extent of about $85,600,000 annually. Accordingly, the construction of the superpower system should be accomplished with a saving in investment cost of about $163,000,000 during the next 10 years.

TABLE 68.—*Investment cost for the superpower system for 1919, 1925, and 1930, in thousands of dollars.*

	Eastern New England.	Western New England.	Mohawk-Hudson.	Metropolitan.	Anthracite.	Southern.	Superpower zone.
1919.							
Present steam-electric plants	66,235	24,550	7,200	129,105	22,586	79,543	329,219
New steam-electric plants	41,100	29,890	20,920	[a] 43,570	[a] 33,000	50,035	218,515
	107,335	54,440	28,120	172,675	55,586	129,578	547,734
Present hydroelectric plants	16,501	16,713	26,135	2,550	1,265	23,963	87,127
New hydroelectric plants	.....	9,000	20,124	25,700	.....	33,000	87,824
	16,501	25,713	46,259	28,250	1,265	56,963	174,951
All power plants	123,836	80,153	74,379	200,925	56,851	186,541	722,685
Transmission lines	4,131	6,343	6,108	13,345	3,635	15,009	48,571
Substations	3,656	1,902	3,149	10,955	3,253	6,183	29,098
Transmission system	7,787	8,245	9,257	24,300	6,888	21,192	77,669
Total investment cost	131,623	88,398	83,636	225,225	63,739	207,733	800,354
Debit or credit to other divisions	.....	.....	−3,800	+3,800	+2,655	−2,655	.....
Total investment cost to division	131,623	88,398	79,836	229,025	66,394	205,078	800,354
Investment made as of midyear, 1919	82,736	41,263	33,335	131,655	23,851	103,506	416,346
New money required	48,887	47,135	46,501	97,370	42,543	101,572	384,008
1925.							
Present steam-electric plants	66,235	24,550	7,200	129,105	22,586	79,543	329,219
New steam-electric plants	50,700	33,100	26,850	[a] 62,700	[a] 29,420	76,120	278,890
	116,935	57,650	34,050	191,805	52,006	155,663	608,109
Present hydroelectric plants	16,501	16,713	26,135	2,550	1,265	23,963	87,127
New hydroelectric plants	.....	9,000	20,124	25,700	.....	33,000	87,824
	16,501	25,713	46,259	28,250	1,265	56,963	174,951
All power plants	133,436	83,363	80,309	220,055	53,271	212,626	783,060

[a] Includes a portion of the Pittston plant investment.

TABLE 68.—*Investment cost for the superpower system for 1919, 1925, and 1930, in thousands of dollars*—Continued.

	Eastern New England.	Western New England.	Mohawk-Hudson.	Metropolitan.	Anthracite.	Southern.	Superpower zone.
1925—Continued.							
Transmission lines	5,186	6,346	6,108	13,345	4,085	15,009	50,079
Substations	5,102	3,655	3,226	12,436	4,163	7,768	36,350
Transmission system	10,288	10,001	9,334	25,781	8,248	22,777	86,429
Total investment cost	143,724	93,364	89,643	245,836	61,519	235,403	869,489
Debit or credit to other divisions	.....	+5,980	−780	−5,200	+1,435	−1,435	.....
Total investment cost to division	143,724	99,344	88,863	240,636	62,954	233,968	869,489
Investment made as of midyear, 1919	82,736	41,263	33,335	131,655	23,851	103,506	416,346
New money required	60,988	58,081	55,528	108,981	39,103	130,462	453,143
1930.							
Present steam-electric plants	66,235	24,550	7,200	129,105	22,586	79,543	329,219
New steam-electric plants	91,750	42,280	39,195	[a] 103,100	[a] 42,800	111,050	430,175
	157,985	66,830	46,395	232,205	65,386	190,593	759,394
Present hydroelectric plants	16,501	16,713	26,135	2,550	1,265	23,963	87,127
New hydroelectric plants	.....	29,000	38,350	51,500	.....	40,000	158,850
	16,501	45,713	64,485	54,050	1,265	63,963	245,977
All power plants	174,486	112,543	110,880	286,255	66,651	254,556	1,013,535
Transmission lines	5,186	11,840	7,956	14,369	4,310	16,440	60,101
Substations	5,730	5,612	4,371	14,606	4,765	9,008	44,092
Transmission system	10,916	17,452	12,327	28,975	9,075	25,448	104,193
Total investment cost	185,402	129,995	123,207	315,230	75,726	280,004	1,109,564
Debit or credit to other divisions	.....	+7,800	−480	−7,320	+18,340	−18,340	.....
Total investment cost to division	185,402	137,795	122,727	307,910	94,066	261,664	1,109,564
Investment made as of midyear, 1919	82,736	41,263	33,335	131,655	23,851	103,506	416,346
New money required	102,666	96,532	89,392	176,255	70,215	158,158	693,218

[a] Includes a portion of the Pittston plant investment.

COST OF POWER.

Table 72 gives the annual production cost of the power plants for the superpower zone, Table 73 the annual transmission-system cost, and Table 74 the total cost of power delivered to load centers.

The costs given in Appendix B consider only production by the electric utilities and represent the cost of power at their bus bars. These costs, compared to the production cost of all the plants of the superpower system, are as follows:

TABLE 69.—*Production cost per kilowatt-hour net generated.*

	1919	1925	1930
Cost for electric utilities, 1919:			
Steam-electric	$0.0212	$0.0212	$0.0212
Hydroelectric	.0094	.0094	.0094
All plants	.0193	.0193	.0193
Cost for superpower system:			
Steam-electric	.0108	.0107	.0102
Hydroelectric	.0061	.0061	.0058
All plants	.0098	.0098	.0093
Reduction by superpower system	.0095	.0095	.0100

To the production cost of the superpower system must be added the transmission cost to determine the cost of power delivered at the load centers.

The average unit cost of power delivered by the superpower system to the load centers is stated below.

TABLE 70.—*Unit cost of power delivered to load centers.*

	1919		1925		1930	
	Per kilowatt-hour.	Per kilowatt-year of demand.	Per kilowatt-hour.	Per kilowatt-year of demand.	Per kilowatt-hour.	Per kilowatt-year of demand.
Operating cost	$0.0045	$17.85	$0.0050	$20.40	$0.0046	$19.10
Fixed charges	.0064	25.40	.0058	24.00	.0056	23.10
General expense	.0004	1.55	.0004	1.60	.0004	1.60
	.0113	44.80	.0112	46.00	.0106	43.80

TABLE 71.—*Annual cost for power delivered to load centers by superpower system and cost for independent operation under conditions of 1919.*

	1919	1925	1930
Independent operation (power plants only):			
Fuel	$125,000,000	$151,000,000	$203,800,000
Maintenance, labor, and supplies	47,905,000	69,425,000	93,440,000
Fixed charges and general expense	190,300,000	227,150,000	305,900,000
	363,205,000	447,575,000	603,140,000
Superpower operation (power plants and transmission system):			
Fuel	61,815,000	87,216,000	108,094,000
Maintenance, labor, and supplies	24,829,000	27,451,000	33,905,000
Fixed charges and general expense	130,511,000	142,638,000	182,608,000
	217,155,000	257,305,000	324,607,000
Saving by superpower operation:			
Fuel	63,185,000	63,784,000	95,706,000
Maintenance, labor, and supplies	23,076,000	41,974,000	59,535,000
Fixed charges and general expenses	59,789,000	84,512,000	123,292,000
	146,050,000	190,270,000	278,533,000

The estimated fuel saving for 1925 is very little greater in dollars than that for 1919, owing to the lower unit coal cost per ton for superpower operation in the earlier year. The cost of power for independent operation is computed on the 1919 unit cost given in Appendix B. The value of fuel saving as here stated will therefore not check with the value given on page 163, where a definite cost per ton has been used in obtaining the result.

The total investment in electric-utility company plants in 1919, as shown by reproduction cost, was $598,277,000. Plants to the value of $416,346,000 are to be incorporated in the superpower system, leaving plants to be abandoned represented by a reproduction cost of $181,931,000.

The net saving effected by the superpower system is arrived at by deducting from the gross saving the cost of money, taxes, insurance, and sinking fund on these abandoned plants, the investment in which must be gradually amortized. The cost of money, insurance, and taxes on the abandoned plants will amount to $21,800,000 a year, and a sinking fund of $17,800,000 a year will amortize the investment in these plants in about eight years on a 7 per cent annuity basis. The deduction from the gross saving is therefore $39,600,000 a year, and the net savings are for 1919, $106,450,000; for 1925, $150,670,000; for 1930, $238,933,000.

If in 1930 the superpower zone were supplied with power from an interconnected system in which all the new power plants were of the steam-electric type and were located as close to the load centers as the available supply of condensing water would permit, the total investment in such a system would be $1,064,716,000, and the annual cost of power delivered to the load

centers would be $348,084,000. The combination of base-load steam-electric plants located both at tidewater and in the anthracite mining region with hydroelectric plants increases the investment cost to $1,109,564,000 but reduces the annual cost of power delivered to the load centers to $278,534,000—a saving of $69,550,000 annually on an increased investment of $44,838,000.

By taking advantage of the partial regional diversity existing between the Anthracite division and the Southern and Metropolitan divisions and by producing large blocks of power in the Sunbury, Nescopeck, and Pittston base-load steam-electric plants in connection with the development of the Delaware River project to carry peak loads, as recommended for 1930, and by transmitting such of this power as is not absorbed by the Anthracite division to the Metropolitan and Southern divisions over the 220,000-volt transmission lines shown on Plates II and III, power could be delivered to these three divisions at the low average cost of 9.7 mills per kilowatt-hour. On the other hand, if the diversity existing between these divisions were ignored and the power were produced in steam-electric plants located as near the centers where it is used as the available supply of condensing water would permit, and if there were no transmission-line connection between the Anthracite and the Metropolitan and Southern divisions, the corresponding cost of power delivered to the load centers of these divisions would be 10.8 mills per kilowatt-hour.

As it will require about eight years to construct the proposed St. Lawrence hydroelectric works and about the same length of time to obtain additional capacity at Niagara Falls that could be released to the superpower zone, the load requirements of 1930 must be met by other facilities. However, if these developments were completed by 1930, the load growth in the Eastern New England, Western New England, and Mohawk-Hudson divisions should be sufficient to absorb the available output of the St. Lawrence by 1932, and that of the Metropolitan division should be sufficient to absorb 300,000 kilowatts at a load factor of 80 per cent from Niagara in the same year. It is believed from consultation with the best-informed authorities on these two projects that power could be purchased from them at not more than $20 per horsepower-year delivered at their bus bars, and accordingly this figure is used in determining their effect on the cost of power to those divisions of the superpower zone so supplied.

The estimated average cost for St. Lawrence power delivered in 1932 at Utica and Schenectady, N. Y., and Northampton, Mass., is 4.6 mills per kilowatt-hour for 600,000 kilowatts at a load factor of 80 per cent. The total annual cost for all power delivered in 1932 to the load centers of the Eastern New England, Western New England, and Mohawk-Hudson divisions with St. Lawrence power would be $130,273,000. Were the excess energy requirement of 1932 over that of 1930 furnished by new steam-electric plants, the total cost would be $141,601,000. The development of St. Lawrence River would therefore save $11,328,000 annually to these geographic divisions. The total investment required for equipment to use St. Lawrence purchased power would be $24,826,000 less than that required if new steam-electric plants were constructed to supply this excess energy. In the Eastern New England, Western New England, and Mohawk-Hudson divisions, which lie farthest from the coal fields, the cost of power generated by steam-electric plants is inherently high, and therefore the St. Lawrence development will be of very great benefit to these divisions.

The Metropolitan division by 1932 can absorb 300,000 kilowatts of Niagara power delivered at a load factor of 80 per cent. The cost of this power delivered at Paterson, N. J., will be about 5.7 mills per kilowatt-hour. The total cost to the Metropolitan division for the power it will require in 1932, if Niagara power is used, will be $107,651,000. If the growth in energy required between 1930 and 1932 were supplied from new steam-electric plants located in the Metropolitan division, the total cost for power to the division in that year would be $110,899,000, showing a saving of $3,248,000 in favor of Niagara power. Were the power purchased from the Niagara power interests, so that no investment by the superpower system in hydroelectric power plants at that location would be required, the total added investment for 1932 would be $5,080,000 less than that which would be required if the Niagara power were displaced by steam-electric power.

TABLE 72.—*Total annual production cost for superpower system for 1919, 1925, and 1930.*

Geographic division.	Annual operating cost.				Annual fixed charges.	Annual production cost.	
	Fuel.	Labor, maintenance, and supplies.	Total.	Per kilowatt-hour.		Total.	Per kilowatt-hour.
1919.							
Eastern New England:							
Steam-electric plants—							
Present	$4,132,000	$2,655,000	$6,787,000	$0.0131	$10,606,000	$17,393,000	$0.0336
New	8,620,000	1,490,000	10,110,000	.0043	6,580,000	16,690,000	.0070
	12,752,000	4,145,000	16,897,000	.0058	17,186,000	34,083,000	.0118
Hydroelectric plants—							
Present	.....	388,000	388,000	.0014	2,394,000	2,782,000	.0104
New	.....	.....	.....	.....	.....	.....	.....
	.....	388,000	388,000	.0014	2,394,000	2,782,000	.0104
All plants	12,752,000	4,533,000	17,285,000	.0055	19,580,000	36,865,000	.0117
Western New England:							
Steam-electric plants—							
Present	851,000	942,000	1,793,000	.0233	3,928,000	5,721,000	.0743
New	4,130,000	996,000	5,126,000	.0047	4,785,000	9,911,000	.0091
	4,981,000	1,938,000	6,919,000	.0059	8,713,000	15,632,000	.0133
Hydroelectric plants—							
Present	.....	438,000	438,000	.0013	2,477,000	2,915,000	.0086
New	.....	100,000	100,000	.0004	1,156,000	1,2561000	.0055
	.....	538,000	538,000	.0009	3,633,000	4,171,000	.0073
All plants	4,981,000	2,476,000	7,457,000	.0043	12,346,000	19,803,000	.0114
Mohawk-Hudson:							
Steam-electric plants—							
Present	272,000	212,000	484,000	.0242	1,153,000	1,637,000	.082
New	2,180,000	640,000	2,820,000	.0047	3,350,000	6,170,000	.0102
	2,452,000	852,000	3,304,000	.0053	4,503,000	7,807,000	.0125
Hydroelectric plants—							
Present	.....	446,000	446,000	.0012	3,787,000	4,233,000	.0117
New	.....	200,000	200,000	.0005	2,615,000	2,815,000	.0074
	.....	646,000	646,000	.0008	6,402,000	7,048,000	.0095
All plants	2,452,000	1,498,000	3,950,000	.0029	10,905,000	14,855,000	.0109
Metropolitan:							
Steam-electric plants—							
Present	16,550,000	6,343,000	22,893,000	.0077	20,657,000	43,550,000	.0147
New	5,878,000	1,622,000	7,500,000	.0043	6,980,000	[a]14,480,000	.0083
	22,428,000	7,965,000	30,393,000	.0068	27,637,000	58,030,000	.0130
Hydroelectric plants—							
Present	.....	67,000	67,000	.003	370,000	437,000	.0198
New	.....	350,000	350,000	.0004	3,380,000	3,730,000	.0044
	.....	417,000	417,000	.0005	3,750,000	4,167,000	.0048
All plants	22,428,000	8,382,000	30,810,000	.0057	31,387,000	62,197,000	.0115
Anthracite:							
Steam-electric plants—							
Present	2,752,000	1,007,000	3,758,000	.007	3,614,000	7,372,000	.0137
New	4,135,000	1,395,000	5,530,000	.0028	5,280,000	[a]10,810,000	.0055
	6,887,000	2,401,000	9,288,000	.0035	8,894,000	18.182,000	.0068

[a] Includes a portion of the annual production cost of the Pittston plant.

TABLE 72.—*Total annual production cost for superpower system for 1919, 1925, and 1930*—Continued.

Geographic division.	Annual operating cost.				Annual fixed charges.	Annual production cost.	
	Fuel.	Labor, maintenance, and supplies.	Total.	Per kilowatt-hour.		Total.	Per kilowatt-hour.
1919—Continued.							
Anthracite—Continued.							
Hydroelectric plants—							
Present	.....	$64,000	$64,000	$0.004	$183,000	$247,000	$0.0155
New	.....	.....	.....	.....	.....	.....	.....
	.....	64,000	64,000	.004	183,000	247,000	.0155
All plants	$6,887,000	2,465,000	9,352,000	.0035	9,077,000	18,429,000	.0067
Southern:							
Steam-electric plants—							
Present	4,270,000	1,481,000	5,751,000	.0099	12,662,000	18,413,000	.0318
New	8,045,000	1,939,000	9,984,000	.0034	8,000,000	17,984,000	.0061
	12,315,000	3,420,000	15,735,000	.0045	20,662,000	36,397,000	.0140
Hydroelectric plants—							
Present	.....	340,000	340,000	.0063	3,475,000	3,815,000	.007
New	.....	395,000	395,000	.0003	4,280,000	4,675,000	.0033
	.....	735,000	735,000	.0004	7,755,000	8,490,000	.0043
All plants	12,315,000	4,155,000	16,470,000	.0030	28,417,000	44,887,000	.0082
Superpower system:							
Steam-electric plants—							
Present	28,827,000	12,639,000	41,466,000	.0088	52,620,000	94,086,000	.0201
New	32,988,000	8,082,000	41,070,000	.0037	34,975,000	76,045,000	.0069
	61,815,000	20,721,000	82,536,000	.0053	87,595,000	170,131,000	.0108
Hydroelectric plants—							
Present	.....	1,743,000	1,743,000	.0011	12,686,000	14,429,000	.0093
New	.....	1,045,000	1,045,000	.0004	11,431,000	12,476,000	.0043
	.....	2,788,000	2,788,000	.0006	24,117,000	26,905,000	.0061
All plants	61,815,000	23,509,000	85,324,000	.0042	111,712,000	197,036,000	.0098
1925.							
Eastern New England:							
Steam-electric plants—							
Present	4,928,000	2,655,000	7,583,000	.0147	10,606,000	18,189,000	.0352
New	12,435,000	1,830,000	14,265,000	.0051	8,120,000	22,385,000	.0080
	17,363,000	4,485,000	21,848,000	.0066	18,726,000	40,574,000	.0122
Hydroelectric plants—							
Present	.....	388,000	388,000	.0014	2,394,000	2,782,000	.0104
New	.....	.....	.....	.....	.....	.....	.....
	.....	388,000	388,000	.0014	2,394,000	2,782,000	.0104
All plants	17,363,000	4,873,000	22,236,000	.0062	21,120,000	43,356,000	.0121
Western New England:							
Steam-electric plants—							
Present	1,029,000	942,000	1,971,000	.0256	3,928,000	5,899,000	.0767
New	5,600,000	1,100,000	6,700,000	.0055	5,293,000	11,993,000	.0098
	6,629,000	2,042,000	8,671,000	.0067	9,221,000	17,892,000	.0138

TABLE 72.—*Total annual production cost for superpower system for 1919, 1925, and 1930*—Continued.

Geographic division.	Annual operating cost.				Annual fixed charges.	Annual production cost.	
	Fuel.	Labor, maintenance, and supplies.	Total.	Per kilowatt-hour.		Total.	Per kilowatt-hour.
1925—Continued.							
Western New England—Con.							
Hydroelectric plants—							
Present	.....	$438,000	$438,000	$0.0013	$2,477,000	$2,915,000	$0.0085
New	.....	100,000	100,000	.0004	1,156,000	1,256,000	.0055
	.....	538,000	538,000	.0009	3,633,000	4,171,000	.0073
All plants	$6,629,000	2,580,000	9,209,000	.0049	12,854,000	22,063,000	.0118
Mohawk-Hudson:							
Steam-electric plants—							
Present	324,000	212,000	536,000	.0268	1,153,000	1,689,000	.0844
New	4,380,000	890,000	5,270,000	.0051	4,296,000	9,566,000	.0092
	4,704,000	1,102,000	5,806,000	.0055	5,449,000	11,255,000	.0106
Hydroelectric plants—							
Present	.....	446,000	446,000	.0012	3,787,000	4,233,000	.0117
New	.....	200,000	200,000	.0005	2,615,000	2,815,000	.0074
	.....	646,000	646,000	.0009	6,402,000	7,048,000	.0095
All plants	4,704,000	1,748,000	6,452,000	.0036	11,851,000	18,303,000	.0102
Metropolitan:							
Steam-electric plants—							
Present	19,800,000	6,343,000	26,143,000	.0088	20,657,000	46,800,000	.0158
New	12,190,000	2,419,000	14,609,000	.0048	10,030,000	[a] 24,639,000	.077
	31,990,000	8,762,000	40,752,000	.0071	30,687,000	71,439,000	.0123
Hydroelectric plants—							
Present	.....	67,000	67,000	.0030	370,000	437,000	.0198
New	.....	350,000	350,000	.0004	3,380,000	3,730,000	.0044
	.....	417,000	417,000	.0005	3,750,000	4,167,000	.0048
All plants	31,990,000	9,179,000	41,169,000	.0061	34,437,000	75,606,000	.0112
Anthracite:							
Steam-electric plants—							
Present	3,046,000	1,006,000	4,052,000	.0075	3,614,000	7,666,000	.0143
New	4,025,000	1,256,000	5,281,000	.0031	4,710,000	[a] 9,991,000	.0058
	7,071,000	2,262,000	9,333,000	.0037	8,324,000	17,657,000	.0071
Hydroelectric plants—							
Present	.....	64,000	64,000	.0040	183,000	247,000	.0155
New	.....	.....	.....	.....	.....	.....	.....
	.....	64,000	64,000	.0040	183,000	247,000	.0155
All plants	7,071,000	2,326,000	9,397,000	.0038	8,507,000	17,904,000	.0071
Southern:							
Steam-electric plants—							
Present	4,979,000	1,481,000	6,460,000	.0112	12,662,000	19,122,000	.0331
New	14,480,000	2,960,000	17,440,000	.0040	12,175,000	29,615,000	.0068
	19,459,000	4,441,000	23,900,000	.0048	24,837,000	48,737,000	.0099
Hydroelectric plants—							
Present	.....	340,000	340,000	.0063	3,475,000	3,815,000	.007
New	.....	395,000	395,000	.0003	4,280,000	4,675,000	.0033
	.....	735,000	735,000	.0004	7,755,000	8,490,000	.0043
All plants	19,459,000	5,176,000	24,635,000	.0035	32,592,000	57,227,000	.0083

[a] Includes a portion of the annual production cost of the Pittston plant.

TABLE 72.—*Total annual production cost for superpower system for 1919, 1925, and 1930*—Continued.

Geographic division.	Annual operating cost.				Annual fixed charges.	Annual production cost.	
	Fuel.	Labor, maintenance, and supplies.	Total.	Per kilowatt-hour.		Total.	Per kilowatt-hour.
1925—Continued.							
Superpower system:							
Steam-electric plants—							
Present	$34,106,000	$12,639,000	$46,745,000	$0.0100	$52,620,000	$99,365,000	$0.0212
New	53,110,000	10,455,000	63,565,000	.0043	44,624,000	108,189,000	.0074
	87,216,000	23,094,000	110,310,000	.0057	97,244,000	207,554,000	.0107
Hydroelectric plants—							
Present	.....	1,743,000	1,743,000	.0011	12,686,000	14,429,000	.0093
New	.....	1,045,000	1,045,000	.0004	11,431,000	12,476,000	.0043
	.....	2,788,000	2,788,000	.0006	24,117,000	26,905,000	.0061
All plants	87,216,000	25,882,000	113,098,000	.0048	121,361,000	234,459,000	.0098
1930.							
Eastern New England:							
Steam-electric plants—							
Present	4,995,000	2,852,000	7,847,000	.0148	10,606,000	18,453,000	.0350
New	18,610,000	3,063,900	21,675,000	.0052	14,685,000	36,360,000	.0088
	23,605,000	5,917,000	29,522,000	.0063	25,291,000	54,813,000	.0117
Hydroelectric plants—							
Present	.....	388,000	388,000	.0014	2,394,000	2,782,000	.0104
New	.....	.....	.....	.....	.....	.....	.....
	.....	388,000	388,000	.0014	2,394,000	2,782,000	.0104
All plants	23,605,000	6,305,000	29,910,000	.0061	27,685,000	57,595,000	.0116
Western New England:							
Steam-electric plants—							
Present	1,029,000	942,000	1,971,000	.0256	3,928,000	5,899,000	.0767
New	5,810,000	1,370,000	7,180,000	.0058	6,775,000	13,955,000	.0113
	6,839,000	2,312,000	9,151,000	.0070	10,703,000	19,854,000	.0151
Hydroelectric plants—							
Present	.....	438,000	438,000	.0013	2,477,000	2,915,000	.0086
New	.....	330,000	330,000	.0004	3,800,000	4,130,000	.0054
	.....	768,000	768,000	.0007	6,277,000	7,045,000	.0064
All plants	6,839,000	3,080,000	9,919,000	.0041	16,980,000	26,899,000	.0112
Mohawk-Hudson:							
Steam-electric plants—							
Present	324,000	212,000	536,000	.0268	1,153,000	1,689,000	.0844
New	5,620,000	1,300,000	6,920,000	.0053	6,270,000	13,190,000	.0100
	5,944,000	1,512,000	7,456,000	.0056	7,423,000	14,879,000	.0112
Hydroelectric plants—							
Present	.....	446,000	446,000	.0013	3,787,000	4,233,000	.0124
New	.....	300,000	300,000	.0003	4,950,000	5,250,000	.0058
	.....	746,000	746,000	.0006	8,737,000	9,483,000	.0077
All plants	5,944,000	2,258,000	8,202,000	.0032	16,160,000	24,362,000	.0095

TABLE 72.—*Total annual production cost for superpower system for 1919, 1925, and 1930*—Continued.

Geographic division.	Annual operating cost.				Annual fixed charges.	Annual production cost.	
	Fuel.	Labor, maintenance, and supplies.	Total.	Per kilowatt-hour.		Total.	Per kilowatt-hour.
1930—Continued.							
Metropolitan:							
Steam-electric plants—							
Present	$15,763,000	$5,992,000	$21,755,000	$0.0096	$20,657,000	$42,412,000	$0.0186
New	21,300,000	3,955,000	25,255,000	.0047	16,485,000	[a] 41,740,000	.0076
	37,063,000	9,947,000	47,010,000	.0064	37,142,000	84,152,000	.0103
Hydroelectric plants—							
Present	.....	67,000	67,000	.003	370,000	437,000	.0198
New	.....	650,000	650,000	.0005	6,800,000	7,450,000	.0060
	.....	717,000	717,000	.0005	7,170,000	7,887,000	.0062
All plants	37,063,000	10,664,000	47,727,000	.0055	44,312,000	92,039,000	.0094
Anthracite:							
Steam-electric plants—							
Present	3,046,000	1,006,000	4,052,000	.0075	3,614,000	7,666,000	.0143
New	5,948,000	1,892,000	7,840,000	.0031	6,855,000	[a] 14,695,000	.0057
	8,994,000	2,898,000	11,892,000	.0036	10,469,000	22,361,000	.0067
Hydroelectric plants—							
Present	.....	64,000	64,000	.004	183,000	247,000	.0155
New	.....	.....	.....	.....	.....	.....	.....
	.....	64,000	64,000	.004	183,000	247,000	.0155
All plants	8,994,000	2,962,000	11,956,000	.0036	10,652,000	22,608,000	.0067
Southern:							
Steam-electric plants—							
Present	4,979,000	1,481,000	6,460,000	.0112	12,662,000	19,122,000	.0331
New	20,670,000	4,310,000	24,980,000	.0040	17,765,000	42,745,000	.0069
	25,649,000	5,791,000	31,440,000	.0046	30,427,000	61,867,000	.0091
Hydroelectric plants—							
Present	.....	340,000	340,000	.0006	3,475,000	3,815,000	.0070
New	.....	625,000	625,000	.0003	6,526,000	7,151,000	.0033
	.....	965,000	965,000	.0004	10,001,000	10,966,000	.0040
All plants	25,649,000	6,756,000	32,405,000	.0034	40,428,000	72,833,000	.0077
Superpower system:							
Steam-electric plants—							
Present	30,136,000	12,485,000	42,621,000	.0106	52,620,000	95,241,000	.0238
New	77,958,000	15,892,000	93,850,000	.0044	68,835,000	162,685,000	.0076
	108,094,000	28,377,000	136,471,000	.0054	121,455,000	257,926,000	.0102
Hydroelectric plants—							
Present	.....	1,743,000	1,743,000	.0011	12,686,000	14,429,000	.0094
New	.....	1,905,000	1,905,000	.0004	22,076,000	23,981,000	.0047
	.....	3,648,000	3,648,000	.0006	34,762,000	38,410,000	.0058
All plants	108,094,000	32,028,000	140,119,000	.0044	156,217,000	296,336,000	.0093

[a] Includes a portion of the annual production cost of the Pittston plant.

TABLE 73.—*Annual cost of transmission system for superpower system, 1919, 1925, and 1930.*

Geographic division.	Operating.	Fixed charges.	Total.
1919.			
Eastern New England:			
Transmission lines	$37,000	$578,000	$615,000
Substations	123,000	584,000	707,000
	160,000	1,162,000	1,322,000
Western New England:			
Transmission lines	50,000	887,000	937,000
Substations	51,000	304,000	355,000
	101,000	1,191,000	1,292,000
Mohawk-Hudson:			
Transmission lines	48,000	855,000	903,000
Substations	87,000	504,000	591,000
	135,000	1,359,000	1,494,000
Metropolitan:			
Transmission lines	75,000	1,870,000	1,945,000
Substations	284,000	1,760,000	2,044,000
	359,000	3,630,000	3,989,000
Anthracite:			
Transmission lines	49,000	508,000	557,000
Substations	114,000	520,000	634,000
	163,000	1,028,000	1,191,000
Southern:			
Transmission lines	221,000	2,100,000	2,321,000
Substations	181,000	987,000	1,168,000
	402,000	3,087,000	3,489,000
Superpower system:			
Transmission lines	480,000	6,798,000	7,278,000
Substations	840,000	4,659,000	5,499,000
	1,320,000	11,457,000	12,777,000
1925.			
Eastern New England:			
Transmission lines	48,000	725,000	773,000
Substations	186,000	816,000	1,002,000
	234,000	1,541,000	1,775,000
Western New England:			
Transmission lines	49,000	888,000	937,000
Substations	133,000	585,000	718,000
	182,000	1,473,000	1,655,000
Mohawk-Hudson:			
Transmission lines	48,000	855,000	903,000
Substations	104,000	516,000	620,000
	152,000	1,371,000	1,523,000
Metropolitan:			
Transmission lines	75,000	1,870,000	1,945,000
Substations	347,000	1,990,000	2,337,000
	422,000	3,860,000	4,282,000
Anthracite:			
Transmission lines	19,000	573,000	592,000
Substations	150,000	665,000	815,000
	169,000	1,238,000	1,407,000

TABLE 73.—*Annual cost of transmission system for superpower system, 1919, 1925, and 1930*—Continued.

Geographic division.	Operating.	Fixed charges.	Total.
1925—Continued.			
Southern:			
Transmission lines	$221,000	$2,100,000	$2,321,000
Substations	189,000	1,242,000	1,431,000
	410,000	3,342,000	3,752,000
Superpower system:			
Transmission lines	460,000	7,011,000	7,471,000
Substations	1,109,000	5,814,000	6,923,000
	1,569,000	12,825,000	14,394,000
1930.			
Eastern New England:			
Transmission lines	48,000	725,000	773,000
Substations	194,000	915,000	1,109,000
	242,000	1,640,000	1,882,000
Western New England:			
Transmission lines	78,000	1,660,000	1,738,000
Substations	173,000	896,000	1,069,000
	251,000	2,556,000	2,807,000
Mohawk-Hudson:			
Transmission lines	132,000	1,110,000	1,242,000
Substations	130,000	700,000	830,000
	262,000	1,810,000	2,072,000
Metropolitan:			
Transmission lines	80,000	2,010,000	2,090,000
Substations	426,000	2,335,000	2,761,000
	506,000	4,345,000	4,851,000
Anthracite:			
Transmission lines	24,000	603,000	627,000
Substations	174,000	762,000	936,000
	198,000	1,365,000	1,563,000
Southern:			
Transmission lines	167,000	2,300,000	2,467,000
Substations	253,000	1,440,000	1,693,000
	420,000	3,740,000	4,160,000
Superpower zone:			
Transmission lines	529,000	8,408,000	8,937,000
Substations	1,348,000	7,050,000	8,398,000
	1,877,000	15,458,000	17,335,000

TABLE 74.—*Annual cost of delivered power for the superpower system, 1919, 1925, and 1930.*

Geographic division.	Operating cost.		Fixed charges.	General expense.	Cost of delivered power.	
	Total.	Per kilowatt-hour.			Total.	Per kilowatt-hour.
1919.						
Eastern New England:						
Cost of power produced	$17,445,000	.....	$20,742,000	$1,333,000	$39,520,000	.....
Debit or credit to other divisions	0	.....	0	0	0	.....
Net cost	17,445,000	$0.0058	20,742,000	1,333,000	39,520,000	$0.0131
Western New England:						
Cost of power produced	7,558,000	.....	13,537,000	740,000	21,835,000	.....
Debit or credit to other divisions	0	.....	0	0	0	.....
Net cost	7,558,000	.0045	13,537,000	740,000	21,835,000	.0131
Mohawk-Hudson:						
Cost of power produced	4,085,000	.....	12,264,000	572,000	16,921,000	.....
Debit or credit to other divisions	+540,000	.....	+560,000	+60,000	+1,160,000	.....
Net cost	4,625,000	.0035	12,824,000	632,000	18,081,000	.0137
Metropolitan:						
Cost of power produced	31,169,000	.....	35,017,000	2,320,000	68,506,000	.....
Debit or credit to other divisions	−540,000	.....	−560,000	−60,000	−1,160,000	.....
Net cost	30,629,000	.0055	34,457,000	2,260,000	67,346,000	.0120
Anthracite:						
Cost of power produced	9,515,000	.....	10,105,000	687,000	20,307,000	.....
Debit or credit to other divisions	+3,000,000	.....	+3,200,000	+470,000	+6,670,000	.....
Net cost	12,515,000	.0042	13,305,000	1,157,000	26,977,000	.0090
Southern:						
Cost of power produced	16,872,000	.....	31,504,000	1,690,000	50,066,000	.....
Debit or credit to other divisions	−3,000,000	.....	−3,200,000	−470,000	−6,670,000	.....
Net cost	13,872,000	.0029	28,304,000	1,220,000	43,396,000	.0093
Superpower system	86,644,000	.0045	123,169,000	7,342,000	217,155,000	.0113
1925.						
Eastern New England:						
Cost of power produced	22,470,000	.....	22,661,000	1,580,000	46,711,000	.....
Debit or credit to other divisions	0	.....	0	0	0	.....
Net cost	22,470,000	.0065	22,661,000	1,580,000	46,711,000	.0135
Western New England:						
Cost of power produced	9,391,000	.....	14,327,000	830,000	24,548,000	.....
Debit or credit to other divisions	+680,000	.....	+710,000	+25,000	+1,415,000	.....
Net cost	10,071,000	.0053	15,037,000	855,000	25,963,000	.0136
Mohawk-Hudson:						
Cost of power produced	6,604,000	.....	12,957,000	685,000	20,246,000	.....
Debit or credit to other divisions	+190,000	.....	+210,000	+15,000	+415,000	.....
Net cost	6,794,000	.0038	13,167,000	700,000	20,661,000	.0117
Metropolitan:						
Cost of power produced	41,591,000	.....	38,297,000	2,800,000	82,688,000	.....
Debit or credit to other divisions	−870,000	.....	−910,000	−40,000	−1,820,000	.....
Net cost	40,721,000	.0059	37,387,000	2,760,000	80,868,000	.0117
Anthracite:						
Cost of power produced	9,566,000	.....	9,745,000	677,000	19,988,000	.....
Debit or credit to other divisions	+960,000	.....	+980,000	+165,000	+2,105,000	.....
Net cost	10,526,000	.0040	10,725,000	842,000	22,093,000	.0085

TABLE 74.—*Annual cost of delivered power for the superpower system, 1919, 1925, and 1930*—Continued.

Geographic division.	Operating cost.		Fixed charges.	General expense.	Cost of delivered power.	
	Total.	Per kilowatt-hour.			Total.	Per kilowatt-hour.
1925—Continued.						
Southern:						
Cost of power produced	$25,045,000	.....	$35,934,000	$2,135,000	$63,114,000	.....
Debit or credit to other divisions	−960,000	.....	−980,000	−165,000	−2,105,000	.....
Net cost	24,085,000	$0.0038	34,954,000	1,970,000	61,009,000	$0.0098
Superpower system	114,667,000	.0050	133,931,000	8,707,000	257,305,000	.0112
1930.						
Eastern New England:						
Cost of power produced	30,152,000	.....	29,325,000	2,081,000	61,558,000	.....
Debit or credit to other divisions	0	.....	0	0	0	.....
Net cost	30,152,000	.0063	29,325,000	2,081,000	61,558,000	.0129
Western New England:						
Cost of power produced	10,170,000	.....	19,536,000	1,038,000	30,744,000	.....
Debit or credit to other divisions	+863,000	.....	+870,000	+62,000	+1,795,000	.....
Net cost	11,033,000	.0045	20,406,000	1,100,000	32,539,000	.0131
Mohawk-Hudson:						
Cost of power produced	8,464,000	.....	17,970,000	890,000	27,324,000	.....
Debit or credit to other divisions	+257,000	.....	+260,000	+18,000	+535,000	.....
Net cost	8,721,000	.0035	18,230,000	908,000	27,859,000	.0110
Metropolitan:						
Cost of power produced	48,233,000	.....	48,657,000	3,390,000	100,280,000	.....
Debit or credit to other divisions	−1,120,000	.....	−1,130,000	−80,000	−2,330,000	.....
Net cost	47,113,000	.0054	47,527,000	3,310,000	97,950,000	.0111
Anthracite:						
Cost of power produced	12,154,000	.....	12,017,000	846,000	25,017,000	.....
Debit or credit to other divisions	+2,160,000	.....	+2,950,000	+120,000	+5,230,000	.....
Net cost	14,314,000	.0040	14,967,000	966,000	30,247,000	.0084
Southern:						
Cost of power produced	32,825,000	.....	44,168,000	2,690,000	79,683,000	.....
Debit or credit to other divisions	−2,160,000	.....	−2,950,000	−120,000	−5,230,000	.....
Net cost	30,665,000	.0036	41,218,000	2,570,000	74,453,000	.0087
Superpower system	141,998,000	.0046	171,673,000	10,935,000	324,606,000	.0106

COST OF POWER DELIVERED TO THE LOAD CENTERS FROM THE NEW POWER PLANTS AND THE TRANSMISSION SYSTEM OF THE SUPERPOWER SYSTEM.

The superpower system as analyzed in the preceding sections comprises two distinct elements—(1) the present power plants incorporated into the system and (2) the new power plants and the transmission system. The amount of new power-plant capacity required is as follows:

TABLE 75.—*New power-plant capacity for superpower system, in kilowatts.*

Geographic division.	1919	1925	1930
Eastern New England	350,000	450,000	810,000
Western New England	320,000	350,000	555,000
Mohawk-Hudson	280,000	340,000	510,000
Metropolitan	423,000	573,000	1,100,000
Anthracite	450,000	450,000	600,000
Southern	695,000	935,000	1,405,000
Superpower zone	2,528,000	3,098,000	4,980,000

The investment cost for the new facilities given in Table 76 is 52.2 per cent of the total investment cost for the superpower system in 1925 and 62.5 per cent of the total in 1930.

The cost of power delivered to the load centers from the new facilities of the superpower system is shown by Table 77 to be 54.3 per cent of the total cost for the superpower system in 1925 and 65 per cent of the total in 1930.

The present power plants proposed for incorporation in the superpower system will be a very important factor in the earlier stages of its being. Although theoretically power could be generated more cheaply and a greater amount of coal could be conserved by abandoning practically every steam-electric power plant now located within the zone, this procedure is not desirable, practicable, or financially possible.

If the power plants retained are operated by the utilities as set forth on pages 157–161, the average cost of power purchased from the new facilities of the superpower system would be $0.0084 per kilowatt-hour measured at the receiving busses of the electric utilities at the load centers. To obtain this result, however, it is essential that all power plants within the zone be so operated that the resulting cost to all concerned will be the lowest. This end can be accomplished only by the operation of the older, less efficient plants for peak load and by the operation of the new, highly efficient plants for base load at high capacity factors.

TABLE 76.—*Investment cost for new power plants and transmission system of the superpower system, 1919, 1925, and 1930, in thousands of dollars.*

	Eastern New England.	Western New England.	Mohawk-Hudson.	Metropolitan.	Anthracite.	Southern.	Superpower zone.
1919.							
New plants	41,100	38,890	41,044	[a] 69,270	[a] 33,000	83,035	306,339
Transmission system	7,787	8,245	9,257	24,300	6,888	21,192	77,669
	48,887	47,135	50,301	93,570	39,888	104,227	384,008
Debit or credit to other divisions	.....	.....	−3,800	+3,800	+2,655	−2,655	.....
Net investment	48,887	47,135	46,501	97,370	42,543	101,572	384,008
1925.							
New plants	50,700	42,100	46,974	[a] 88,400	[a] 29,420	109,120	366,714
Transmission system	10,288	10,001	9,334	25,781	8,248	22,777	86,429
	60,988	52,101	56,308	114,181	37,668	131,897	453,143
Debit or credit to other divisions	.....	+5,980	−780	−5,200	+1,435	−1,435	.....
Net investment	60,988	58,081	55,528	108,981	39,103	130,462	453,143
1930.							
New plants	91,750	71,280	77,545	[a] 154,600	[a] 42,800	151,050	589,025
Transmission system	10,916	17,452	12,327	28,975	9,075	25,448	104,193
	102,666	88,732	89,872	183,575	51,875	176,498	693,218
Debit or credit to other divisions	.....	+7,800	−480	−7,320	+18,340	−18,340	.....
Net investment	102,666	96,532	89,392	176,255	70,215	158,158	693,218

[a] Includes a part of the investment in the Pittston plant.

TABLE 77.—*Cost of power delivered from new power plants and transmission system of superpower system for 1919, 1925, and 1930.*

	Eastern New England.	Western New England.	Mohawk-Hudson.	Metropolitan.	Anthracite.	Southern.	Superpower zone.
1919.							
Power (millions of kilowatt-hours):							
Delivered to division	3,016	1,671	1,313	5,590	3,005	4,669	19,264
Generated by old plants	785	417	381	2,982	553	1,121	6,239
Delivered from new facilities	2,231	1,254	932	2,608	2,452	3,548	13,025
Annual cost (thousands of dollars):							
Production cost, new plants	16,690	11,167	8,985	[a] 18,210	[a] 10,810	22,659	88,521
Transmission cost	1,322	1,292	1,494	3,989	1,191	3,489	12,777
General expense	630	438	358	782	420	915	3,543
	18,642	12,897	10,837	22,981	12,421	27,063	104,841
Debit or credit to other divisions	.....	.....	+1,160	−1,160	+6,670	−6,670	.....
Total cost of power delivered from new facilities	18,642	12,897	11,997	21,821	19,091	20,393	104,841
Cost per kilowatt-hour	$0.0084	$0.0103	$0.0129	$0.0084	$0.0078	$0.0057	$0.0080
1925.							
Power (millions of kilowatt-hours):							
Delivered to division	3,458	1,909	1,767	6,903	2,600	6,233	22,870
Generated by old plants	785	417	381	2,982	553	1,121	6,239
Delivered from new facilities	2,673	1,492	1,386	3,921	2,047	5,112	16,631
Annual cost (thousands of dollars):							
Production cost, new plants	22,385	13,249	12,381	[a] 28,369	[a] 9,991	34,290	120,665
Transmission cost	1,775	1,655	1,523	4,282	1,407	3,752	14,394
General expense	845	522	487	1,140	398	1,330	4,722
	25,005	15,426	14,391	33,791	11,796	39,372	139,781
Debit or credit to other divisions	.....	+1,405	+415	−1,820	+2,105	−2,105	.....
Total cost of power delivered from new facilities	25,005	16,831	14,806	31,971	13,901	37,267	139,781
Cost per kilowatt-hour	$0.0093	$0.0113	$0.0107	$0.0082	$0.0068	$0.0073	$0.0084
1930.							
Power (millions of kilowatt-hours):							
Delivered to division	4,755	2,477	2,526	8,781	3,606	3,567	30,712
Generated by old plants	797	417	361	2,296	553	1,121	5,547
Delivered from new facilities	3,958	2,060	2,165	6,485	3,053	7,446	25,165
Annual cost (thousands of dollars):							
Production cost, new plants	36,360	18,085	18,440	[a] 49,190	[a] 14,695	49,896	186,666
Transmission cost	1,882	2,807	2,072	4,851	1,563	4,160	17,335
General expense	1,330	795	735	1,835	755	1,700	7,150
	39,572	21,687	21,247	55,876	17,013	55,756	211,151
Debit or credit to other divisions	.....	+1,795	+535	−2,330	+5,230	−5,230	.....
Total cost of power delivered from new facilities	39,572	23,482	21,782	53,546	22,243	50,526	211,151
Cost per kilowatt-hour	$0.0100	$0.0114	$0.0101	$0.0083	$0.0073	$0.0068	$0.0084

[a] Includes a part of the annual production cost of the Pittston plant.

APPENDIX F.

STEAM-ELECTRIC PLANTS FOR THE SUPERPOWER SYSTEM.

By HENRY FLOOD, jr., and others of the engineering staff.

EXISTING PLANTS TO BE RETAINED.

CAPACITY AND PERFORMANCE.

The principal factor in determining whether or not a given plant shall be incorporated in the superpower system is fuel performance. Other factors, however, are strategic location for regulation of voltage and the adaptability of the plant to expansion. The total effective capacity to be retained, as shown by Table 78, is 79 per cent of the total effective capacity of the steam-electric plants on December 31, 1919.

TABLE 78.—*Capacity and performance in 1919 of steam-electric plants to be retained in the superpower system.*

Division.	Effective capacity (kilowatts).	Output (millions of kilowatt-hours).	Fuel used (thousands of short tons).	Effective capacity factor (per cent).	Coal used per kilowatt-year of effective capacity (short tons).
Bituminous coal plants:					
Eastern New England	514,580	1,290.4	1,318.5	28.6	2.56
Western New England	171,800	294.4	330.8	19.5	1.93
Mohawk	31,750	21.1	52.0	7.6	1.64
Hudson	14,000	33.1	45.5	26.8	3.25
Metropolitan	1,130,500	3,474.1	3,734.0	35.0	3.30
Anthracite	48,000	164.3	234.9	39.2	4.90
Southern	632,800	2,141.3	1,887.9	38.6	2.98
	2,543,430	7,418.7	7,603.6	33.2	2.90
Anthracite plants:					
Anthracite	111,500	480.2	979.5	29.1	8.78
Southern	21,700	22.0	44.3	11.5	2.04
	133,200	502.2	1,023.8	42.8	7.68
Grand total	2,676,630	7,920.9	8,627.4	33.8	3.23

Figure 26 shows the estimated average fuel performance during 1919 of plants using anthracite and bituminous coal. The plants to be retained that burn bituminous coal are those that use not over 50 per cent more than the plants of type B–3 (see p. 185) and those to be retained that burn anthracite are those that use not over 125 per cent more coal than the plants of type A–3 (see p. 185).

ESTIMATED INVESTMENT COST.

In 1919 there were in operation in the superpower zone 400 steam-electric public-utility plants. Most of these plants were built so long ago that their cost can not readily be estimated. A knowledge of the investment made in existing plants is required for the purpose of computing the fixed charges and the total cost of energy. In comparing the total cost of power produced under a superpower system with the cost of that produced under independent operation the investment cost for each element of both systems must be computed in the same manner.

Figure 27 shows the estimated unit investment cost required for effective plant capacity and for excess generator capacity. Many of the existing plants have insufficient boiler capacity for the entire prime-mover installation, so that it is necessary to estimate the cost of excess generator capacity. These estimates are the result of an examination in detail of the items of cost of plants having capacities between 500 and 175,000 kilowatts. To insure the use of fair cost values authorities on this subject have been consulted freely.

The estimated cost of constructing, in midyear of 1919, the steam-electric plants to be retained in the superpower system is as follows:

Eastern New England	$66,235,000
Western New England	24,550,000
Mohawk	5,030,000
Hudson	2,170,000
Metropolitan	129,105,000
Anthracite	22,586,000
Southern	79,543,000
Superpower zone	329,219,000

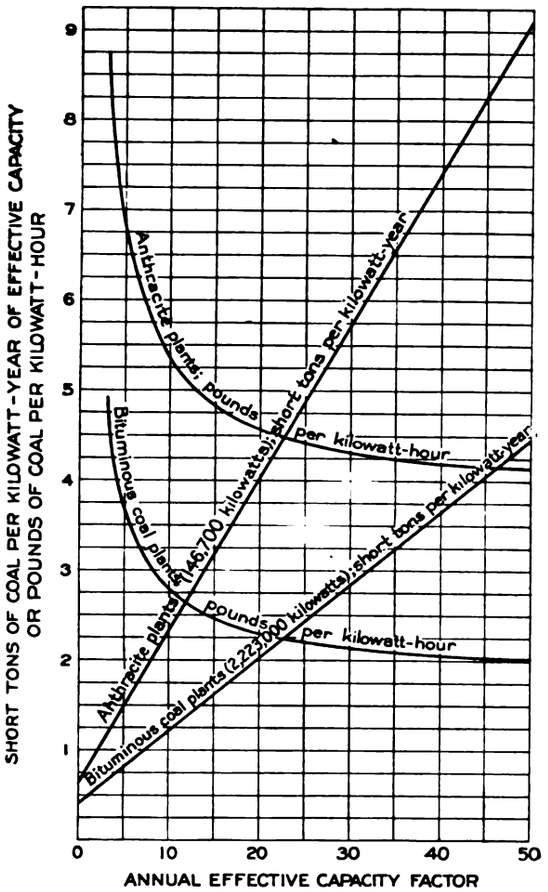


FIGURE 26.—Average performance of existing steam-electric plants to be retained in the superpower system.

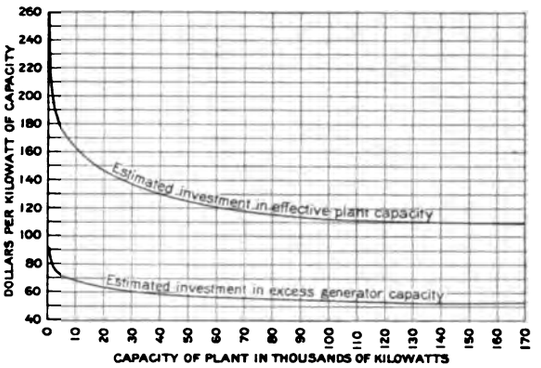


FIGURE 27.—Estimated unit investment for existing steam-electric plants as if constructed in midyear of 1919.

ESTIMATED ANNUAL PRODUCTION COST.

The fixed charges for the plants to be retained, computed at 16 per cent of the investment cost given above, are stated below. (See also Appendix L.) The cost in 1919 for maintenance, labor, and supplies has been used, and the cost of coal as given in Appendix J.

Eastern New England	$10,606,000	Anthracite	$3,614,000
Western New England	3,928,000	Southern	12,662,000
Mohawk	805,000	Superpower zone	52,620,000
Hudson	348,000		
Metropolitan	20,657,000		

Figures 28 and 29 give the average production cost of all existing steam-electric plants to be retained in the superpower system, and in Table 79 the operating cost, fixed charges, and total production costs of these plants are compared to the estimated annual cost of base-load steam-electric plants.

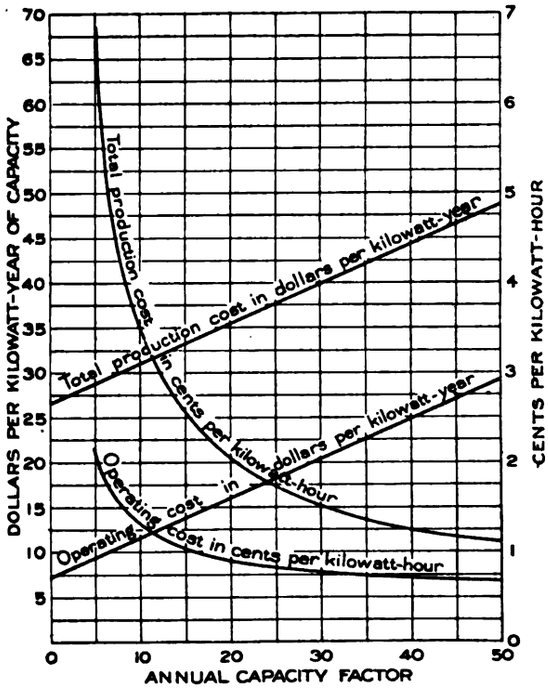


FIGURE 28.—Estimated average production and operating costs for existing steam-electric plants burning bituminous coal to be retained in superpower system. Coal figured at $5.30 per short ton in bunkers.

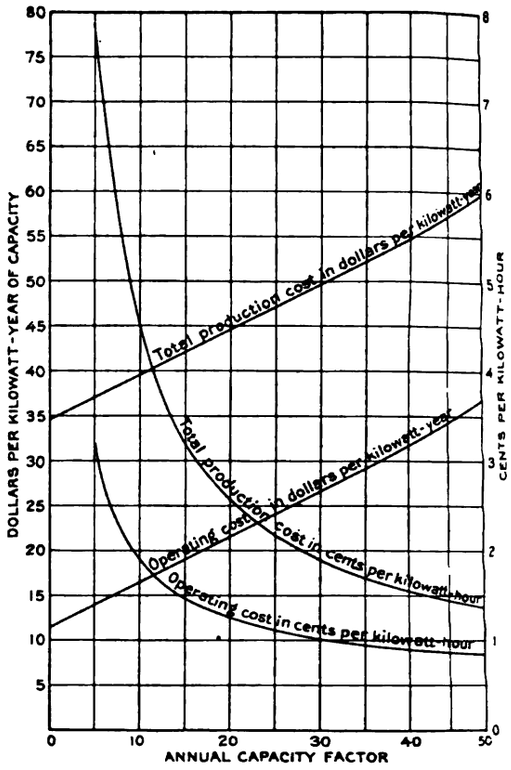


FIGURE 29.—Estimated average cost of production and operation for existing steam-electric plants burning anthracite to be retained in superpower system. Coal figured at $3 per long ton.

TABLE 79.—*Costs for new and retained steam plants, at an annual capacity factor of 30 per cent, in cents per kilowatt-hour.*

	Operating cost.	Fixed charges.	Total production cost.
Plants burning bituminous coal:			
Existing plants retained	0.77	0.73	1.50
Base-load plants	.49	.59	1.08
Difference	.28	.14	.42
Plants burning anthracite:			
Existing plants retained	1.00	.87	1.87
Base-load plants	.42	.65	1.07
Difference	.58	.22	.80

NEW BASE-LOAD PLANTS.

LOCATION, CHARACTER, SIZE, AND DESIGN.

The location of the new base-load steam-electric plants will be determined largely by the availability of condensing water and the convenience and cost of coal delivery and storage.

Except as qualified by character of load and relation to existing hydroelectric and steam-electric plants, the new plants will be operated at high annual capacity factors. To provide flexibility in design and cost the plants will be constructed in multiples of 30,000 kilowatts and may therefore use single-cylinder turbines of 30,000 kilowatts or multiple-cylinder turbines of 60,000 kilowatts.

The maximum size of steam-electric station has been fixed at 360,000 kilowatts. This limit has been determined by considering on the one hand the ability to transmit energy away from the plant and on the other the hazard incident to the possibility of destruction through unusual catastrophe.

It is desirable to standardize as far as may be possible all the units or elements that enter into the construction of a plant, such as boiler equipment, turbines, transformers, and switch gear, in order to reduce the cost of maintenance, to obviate the need of carrying many small parts, and thus, by making quick repairs possible, to insure continuity of service.

After consultation with many representatives of manufacturers of equipment and with designing and operating engineers, the following basic operating requirements for base-load steam-electric plants have been selected:

Steam pressure at turbine throttle, 300 pounds per square inch.
Superheat at turbine throttle, 230° F.
Final temperature at turbine throttle, 652° F.
Absolute pressure at turbine exhaust nozzle, 1 inch of mercury.

These requirements have been thoroughly tried, and conformity with them should assure reliability of service.

Base-load steam-electric plants are of two general types—type A, using anthracite, and type B, using bituminous coal. The two types in turn have been subdivided into three classes—class 1, stokers, boilers, economizers, and air preheaters; class 2, stokers, boilers, and economizers; class 3, stokers and 20-tube high boilers. The stokers for type A are chain grate; those for type B are underfeed. The relative performance of these types, the relative investments, and the relative production costs are discussed in the following sections of this appendix.

The load to be carried on these plants will not include sudden peaks of short duration. Such peaks as they will have to carry will be of long duration. Accordingly, a liberal boiler capacity has been planned for the turbines, ranging from about 4 kilowatts per boiler-horsepower for a plant of class 3 to about 4.65 kilowatts for a plant of class 1. The boiler plant can thus operate at a very high efficiency over the entire range of load. Plants of class 1 can carry about 175 per cent of their rating at normal loads and 215 per cent on sustained peaks; plants of class 3 can carry about 160 per cent on normal loads and 190 per cent on sustained peaks. The boiler and stoker arrangement is so planned, however, that 300 per cent rating can readily be obtained if necessary for peaks of short duration. Large combustion chambers are used, 3½ cubic feet per boiler-horsepower having been allowed.

Should the burning of pulverized or process fuels become profitable in conjunction with the production of power, it will be possible to install the necessary apparatus with little expense, as this contingency has been considered in designing the boiler plant.

With 30,000-kilowatt turbines surface condensers having approximately 50,000 square feet of surface will be used. This amount of surface may be varied at different localities because of local water conditions. Under average conditions of obtaining condensing water for the entire zone this amount of condenser capacity will be ample.

Base-load stations will be located outside of congested centers of population.

ESTIMATED PERFORMANCE.

The estimated performance for base-load steam-electric plants is shown in Plate VIII for plants of types A–3, B–1, B–2, and B–3.

It is not considered advisable to use pressures or temperatures higher than those indicated above, which are in successful use to-day, despite the fact that fuel economy may be increased by higher pressures and temperatures.

The estimate of the performance of plants of type A was based upon the use of No. 3 buckwheat coal having approximately the following characteristics:

Moisture	per cent	10.8
Volatile matter	do	4.8
Fixed carbon	do	71.6
Ash	do	13.8
British thermal units		11.500

The estimate of the performance of plants of type B was based upon the use of coal from the central Pennsylvania fields having the following characteristics:

Moisture	per cent..	2.5
Volatile matter	do....	24.6
Fixed carbon	do....	66.0
Ash	do....	7.0
British thermal units		14,100

The curves in Plate VIII show two performances, one called "acceptance test conditions," meaning the best possible performance that may be expected from the plant, and one called "annual," meaning the performance considered throughout a year. The "annual" performance was estimated according to actual operating conditions, under which the boiler-room equipment can not be kept clean enough to maintain test results, the turbines are lapped at about 75 to 80 per cent load to protect service, the vacuum varies, inferior coal must be used at times, and the boilers are banked when necessary. These actual operating conditions have a large effect on performance. It is planned to operate the base-load plants with a uniform daily load by shifting the load swings either to the existing steam-electric plants or to such hydroelectric plants as may be found suitable for peak-load operation. On the assumption that the thermal efficiency will increase up to 1930 at the present rate the annual performance represented by these estimates is a fair average for expected performance between 1920 and 1930.

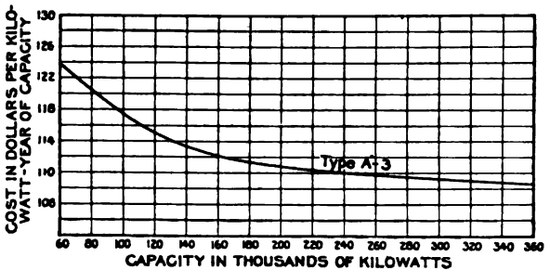


FIGURE 30.—Estimated unit investment cost of base-load steam-electric plants burning anthracite. Based on prices prevailing in midyear of 1919. Type A-3, chain-grate stokers and boilers.

UNIT INVESTMENT COST.

The unit investment costs of plants of the several types considered in figures 30 and 31 are based on the prices of material and labor in the midyear of 1919. These costs will provide sufficient land for a 360,000-kilowatt plant as well as for coal storage and a process coal plant. The main coal-handling system and the main intake and discharge tunnels are adapted to a plant having a minimum capacity of 180,000 kilowatts. Intake and discharge laterals will be added to each unit as turbines are installed. The cost of a 60,000-kilowatt plant therefore includes land sufficient for its development to 360,000 kilowatts and coal-handling facilities and main condenser tunnels for its development to 180,000 kilowatts.

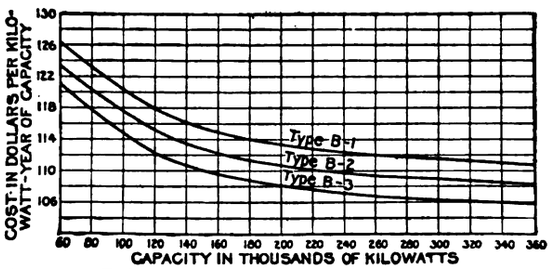
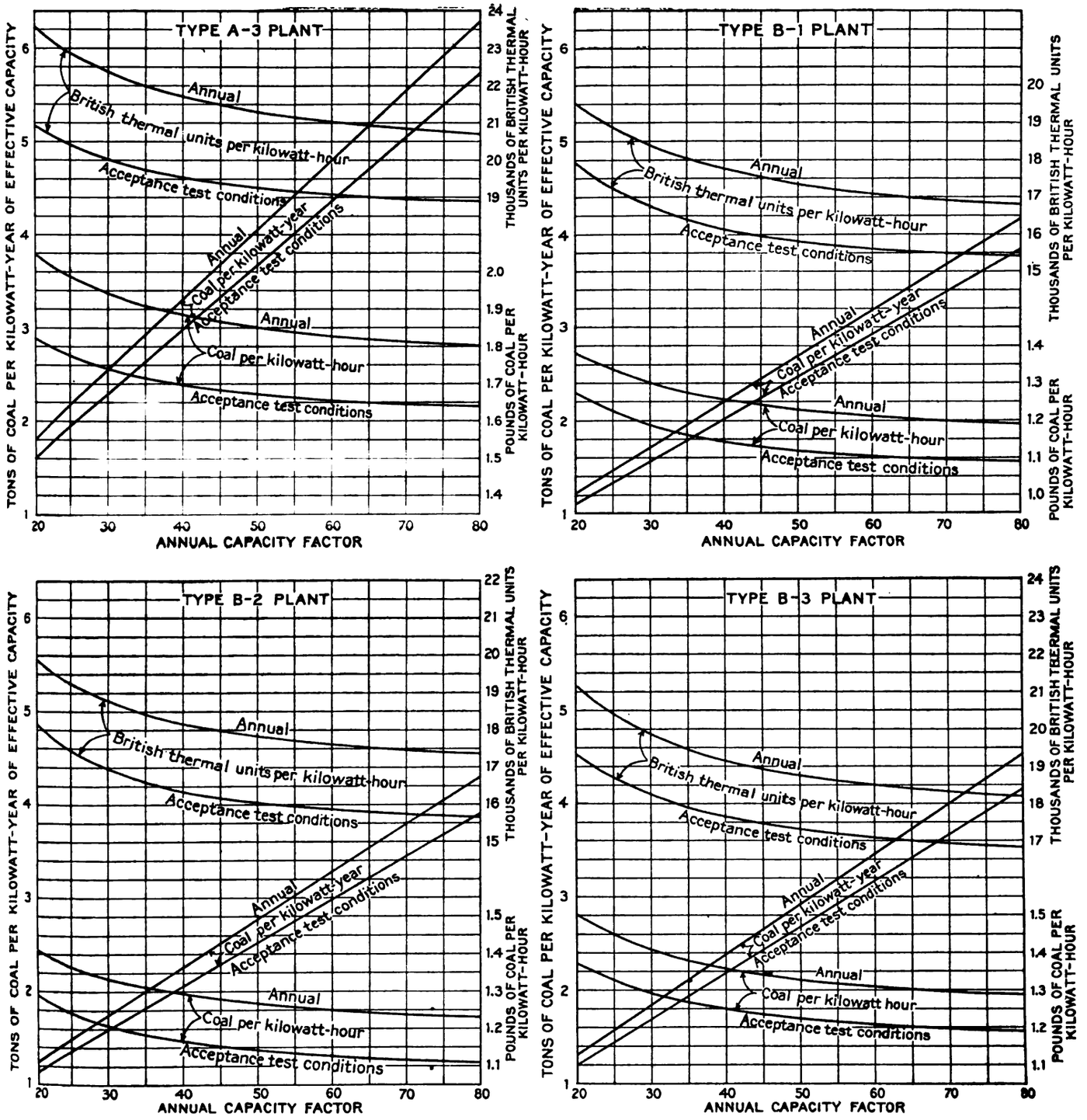


FIGURE 31.—Estimated unit investment cost of base-load steam-electric plants burning bituminous coal. Based on prices prevailing in midyear of 1919. Type B-1, underfeed stokers, boilers, economizers, and preheaters; B-2, underfeed stokers, boilers, and economizers; B-3, underfeed stokers and boilers.

Table 80 shows the estimated cost of three sizes and four types of base-load plants, including the cost of superintendence, engineering, contingencies, and interest during construction.



ESTIMATED UNIT PERFORMANCE OF BASE-LOAD STEAM-ELECTRIC PLANTS.

TABLE 80.—*Estimated unit investment per kilowatt of capacity for base-load steam-electric plants in midyear, 1919.*

Type of plant and capacity in kilowatts.	Real estate and seasonal coal storage.	Boiler house, complete.	Turbine house, complete.	Switching and feeders.	Total.
Type A–3:					
120,000	$3.00	$47.65	$57.20	$7.39	$115.24
240,000	2.10	44.34	56.79	7.37	110.60
360,000	1.80	43.78	55.00	7.36	107.94
Type B–1:					
120,000	3.00	50.10	57.20	7.39	117.69
240,000	2.10	46.71	56.79	7.37	112.89
360,000	1.80	46.13	55.00	7.36	110.29
Type B–2:					
120,000	3.00	47.45	57.20	7.39	115.04
240,000	2.10	44.06	56.79	7.37	110.32
360,000	1.80	43.50	55.00	7.36	107.66
Type B–3:					
120,000	3.00	44.75	57.20	7.39	112.34
240,000	2.10	41.44	56.79	7.37	107.70
360,000	1.80	40.88	55.00	7.36	105.04

UNIT PRODUCTION COST.

Unit production costs are subdivided into operating costs (fuel, maintenance, labor, and supplies) and fixed charges. The costs of maintenance, labor, and supplies for plants using bituminous and anthracite coal, as shown in figure 32, have been determined by detailed analyses of the operations of the largest steam-electric plants in the superpower zone.

The total production cost varies with the type and size of plant and the cost of fuel. Typical costs are shown by the curves in figures 33 and 34 for types B–3 and A–3. The cost of bituminous coal has been fixed at $5.30 per short ton delivered to the plant bunkers, this being the weighted cost for the zone in 1919. The cost of anthracite for plants type A–3 has been fixed at

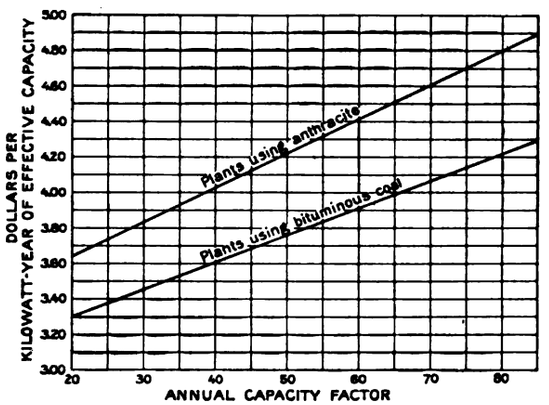


FIGURE 32.—Estimated annual cost of maintenance, labor, and supplies for base-load steam-electric plants. Based on prices prevailing in 1919.

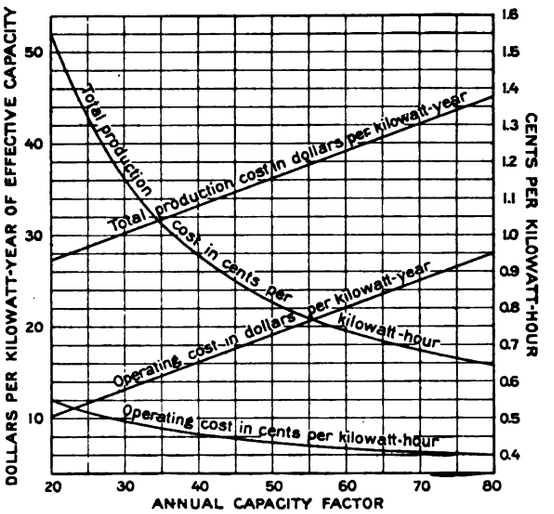


FIGURE 33.—Estimated annual production and operating costs for a plant of type B–3, capacity 300,000 kilowatts. Fuel figured at $5.30 per short ton in bunkers.

$3 per long ton delivered to the plant bunkers, this being approximately the cost at the anthracite mines plus the freight charge.

Greater fuel economy would be gained by installing plants of high efficiency, but such plants (of classes 1 and 2) cost more per unit, and unless the saving in operating cost is so great as to bring a large return on the additional investment their installation is not warranted. By taking a return of 30 per cent on the additional capital required for plants of classes 1 and 2 over that required for plants of class 3 as the point where the installation of plants of classes

1 and 2 is justified, any notable change in conditions that may occur—such as a large reduction in the cost of coal, the development of water power, or the development of much more efficient methods of power production—is largely discounted, for the additional investment will be counterbalanced in three or four years by the 30 per cent additional return on it.

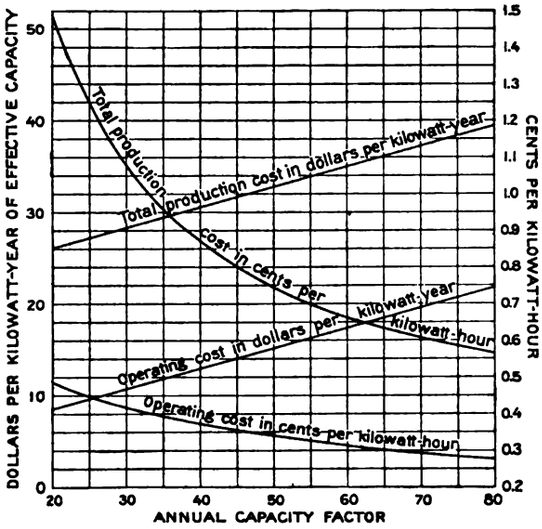


FIGURE 34.—Estimated annual production and operating costs for a plant of type A-3, capacity 300,000 kilowatts. Fuel figured at $3 per long ton in bunkers.

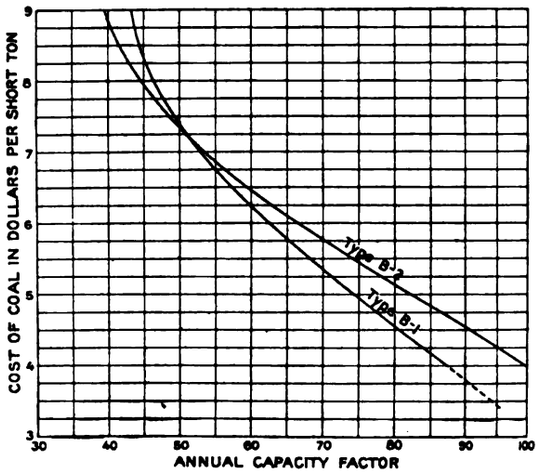


FIGURE 35.—Conditions justifying the use of a plant of type B-1 or B-2 instead of a plant of type B-3. Based on a return of 30 per cent on the additional investment required.

The adoption of plants of different types at different locations has been decided according to the curves in figure 35. The authorities on this subject are of two schools, one advocating a lesser return and the other a greater return than 30 per cent. Figure 35, based upon a 30 per cent return, expresses the average opinion of these two schools.

LOCATION AT TIDEWATER AND ON INLAND RIVERS.

The new base-load steam-electric plants for the superpower system have been so located as to obtain full advantage of low freight rates, available coal-delivery routes, and ample condensing water.

TABLE 81.—*Location and capacity of new base-load steam-electric plants.*

	1925		1930	
	Number of plants.	Capacity (kilowatts).	Number of plants.	Capacity (kilowatts).
Using bituminous coal:				
Boston	1	270,000	2	450,000
New Bedford	.....	.....	1	120,000
Providence	1	180,000	1	240,000
New Haven	1	210,000	1	270,000
Hartford	1	90,000	1	120,000
Utica	1	60,000	1	90,000
Catskill	1	180,000	1	270,000
New York	1	300,000	2	570,000
Newark	1	90,000	1	180,000
Trenton	1	90,000	1	120,000
Philadelphia	1	240,000	2	420,000
Harrisburg	1	120,000	1	180,000
	11	1,830,000	15	3,030,000
Using anthracite:				
Sunbury	1	240,000	1	300,000
Pittston	1	300,000	1	300,000
Nescopeck	1	150,000	1	300,000
	3	690,000	3	900,000
Grand total	14	2,520,000	18	3,930,000

Reference to Appendix E (pp. 164–166) shows that the cost of coal per ton delivered to these proposed new base-load steam-electric plants is lower than to either the steam-electric plants retained or to the electric public utilities for 1919.

The plant locations for 1930 are shown on Plate X (p. 220) with reference to the coal-mining districts, the available coal-delivery routes, and the supply of condensing water. Their locations with respect to the transmission system for both 1925 and 1930 are shown on Plates II and III (p. 14).

For the Anthracite, Metropolitan, and Southern divisions the capacities of the steam-electric power plants have been so determined as to obtain the most economical combination with the hydroelectric plants on Potomac, Susquehanna, and Delaware rivers. Furthermore, the diversity in demand existing between the Anthracite and the Southern and Metropolitan divisions has been considered in determining the capacity of the plants to be installed.

It would have been possible to supply the same amount of power from a smaller number of steam-electric plants having a capacity of about 300,000 kilowatts each, but in order to insure continuity of service the plants have been more widely distributed at a slight increase of cost. However, with such a distribution of plant capacity future demand can be partly met by the enlargement of these plants.

The procedure to be adopted for the development of the hydroelectric resources of the zone has a very important bearing upon the amount of steam-electric capacity to be installed. For instance, in the Mohawk-Hudson division it is proposed to start the development of Hudson River on the assumption of a high load factor, steam-electric plants being used to carry the peak load. This plan calls for the early installation of a relatively large amount of new steam-electric capacity for that division. However, when power from St. Lawrence River is supplied to this division the economical procedure will be to continue the development of Hudson River to handle peak loads and to install practically no further steam-electric capacity until the ultimate limit of development of St. Lawrence and Hudson rivers has been reached.

PLANTS IN THE MINING REGIONS.

The development of electric power within the coal regions is justified when the freight charges on the coal to the points of consumption are greater than the value of the electric energy lost in transmission plus the fixed and operating charges on the transmission system, allowance being made for the saving in capitalization on generating equipment that will be permitted by diversity in loads between the interconnected load centers.

ANTHRACITE FIELDS.

SIZE AND QUALITY OF ANTHRACITE.

Investigation shows that buckwheat No. 3 is the most economical size of anthracite for use on the stokers of superpower plants. The firing of powdered anthracite is being developed but has not yet been brought to the commercial stage. The quality of anthracite from different mines varies, especially as to its ash content. Improved boiler efficiency justifies the cost of ash removal by washing down to a content of about 15 per cent. The performance of steam-electric plants using anthracite is based upon coal having the following analysis: Moisture 9.8 per cent, volatile matter 4.6 per cent, fixed carbon 71.6 per cent, ash 13.8 per cent, British thermal units 11,500.

QUANTITY OF ANTHRACITE AVAILABLE.

Doubtless the peak of production of anthracite was reached during the World War, the output from the mines during that period being reinforced by washeries which reclaimed great quantities of the finer sizes of coal from culm banks. Most of the coal of size No. 3 has now been removed from the banks. There is no indication, however, that there will be any considerable falling off in the production of freshly mined coal for many years, and there is no reason for any appreciable change in the ratio of the smaller sizes to the total output. The statistics of the last few years are therefore a reliable indication of the quantity of buckwheat

No. 3 available for many years. The table given below is taken from a report of the United States Geological Survey on the production of Pennsylvania anthracite in 1919, by F. G. Tryon, supplemented by data obtained from the Anthracite Bureau of Information. The figures in the last column are a close approximation of the total output of buckwheat No. 3, for although no complete records are available upon the size of the fuel used by the mines, data obtained from individual mines indicate that it is almost exclusively buckwheat No. 3.

TABLE 82.—*Anthracite produced in 1916–1919, in long tons.*

Year.	Total.	Mine fuel used for power and heating.[a]	Mine fuel used for power.	Buckwheat No. 3 sold.	Buckwheat No. 3 produced.[b]
1916	78,195,083	8,715,071	7,933,120	3,326,879	11,259,999
1917	88,939,117	9,321,965	8,432,573	3,136,337	11,568,910
1918	88,237,526	9,128,526	8,246,151	5,174,403	13,420,554
1919	78,653,751	8,573,580	7,787,043	2,377,000	10,164,043

[a] Probably almost exclusively buckwheat No. 3. [b] Determined by assuming that all the mine fuel used for power is buckwheat No. 3.

Estimates of the future supply of buckwheat No. 3 will show some reduction from the above figures, which include coal from washeries. Tryon in the report cited above states that 1,650,000 tons of freshly mined buckwheat No. 3 was sold and 7,721,545 tons of freshly mined fuel was used for mine operations in 1919. It is estimated that the annual production of this size for the next 10 years should average about 9,000,000 tons.

If all the mines are electrified, the coal thus released will be sufficient to serve all the demands for power at the mines and in addition to operate at their full capacity all the public-utility plants that now serve New York City, New Jersey, and the Philadelphia district.

POSSIBLE SITES IN THE ANTHRACITE REGION.

The following streams within the anthracite region have been investigated with reference to their suitability for supplying condensing water: Portions of Susquehanna, Schuylkill, Lackawanna, and Lehigh rivers; Shamokin, Mahonoy, Mahantango, Wiconisco, Wapwallowpen, Nescopeck, Catawissa, and Roaring creeks. All except the Susquehanna have been eliminated because of low flow, contamination, or both. Three sites on Susquehanna River are suggested—one north of Pittston, one near the mouth of Nescopeck Creek, and the third south of Sunbury. At each of these points the water conditions are favorable for a 300,000-kilowatt plant. An adequate supply of suitable coal can be obtained within a radius of 25 miles. The length of haul is a minimum at Pittston.

COST OF ENERGY FROM PLANTS IN THE ANTHRACITE REGION.

Appendix E shows that by 1930 the total energy requirements of the Anthracite division should reach 3,606,000,000 kilowatt-hours, corresponding to a maximum demand of 785,000 kilowatts. The total generating capacity of the public-utility companies now serving the division is 230,000 kilowatts. Minimum operating cost would be obtained by carrying the entire load from the superpower system, but in order to conserve capital the more efficient of the present plants will be retained.

The sizes of the plants and their location in the Anthracite division, together with their relation if interconnected with Delaware River, are discussed in Appendix E. The combination of the plants in the coal-mining region with Delaware River shows the greatest economic possibility to the Anthracite, Metropolitan, and Southern divisions. In view of the fact that the Anthracite division load reaches a maximum in the morning and falls off rapidly after 3 o'clock in the afternoon, there is considerable diversity between this load and the loads in adjacent territories. Furthermore, the anthracite mines operate on an average only 225 days in the year, so there is further diversity between the mines. If there were an interconnected system between the Anthracite and the other divisions considerable off-peak capacity would be available in the Anthracite division for supplying power to the Metropolitan and Southern divisions.

BITUMINOUS COAL FIELDS.

GENERAL CONDITIONS.

On account of the adequate stream flow and the proximity of the Anthracite division to the superpower zone, steam-electric power in that division is an economic possibility. These favorable conditions, however, do not prevail in the bituminous coal region, nor will the power requirement of the southern load centers by 1930 be sufficiently high to permit the economical transmission of power from the bituminous coal fields.

POSSIBLE SITES IN THE BITUMINOUS COAL REGION.

Only three large streams flow from the eastern slope of the Allegheny Mountains—the West Branch of the Susquehanna, the Juniata, and the Potomac. The highest point on Susquehanna River deserving consideration in this connection is at Keating, where Sinnemahoning Creek joins the river. This point is about 20 miles from the Clearfield district, the nearest locality at which an adequate supply of coal can be obtained. The flow at Keating derived from stream-flow records at Renovo indicates that the output during dry periods would be limited to less than 100,000 kilowatts.

Below the junction of the Frankstown and Raystown branches of Juniata River, near Huntingdon, the water supply is insufficient for a plant of a capacity exceeding 180,000 kilowatts. At either Huntingdon or Mount Union railroad facilities are available for obtaining coal from the Broad Top field with a maximum haul of 30 miles, and the distance from Huntingdon to the Philipsburg district is 45 miles.

The West Branch of Potomac River reaches the coal fields near Cumberland, Md. At this point the local power company has a steam plant whose ultimate capacity is limited by the supply of water to about 30,000 kilowatts. About 30 miles below Cumberland, near Green Spring, the South Branch adds a large volume of water, which will permit increasing the capacity to 180,000 kilowatts.

A condition precedent for the economical transmission of power to tidewater is a capacity for delivered power of about 300,000 kilowatts, with transmission at a very high load factor. Sufficient condensing water is not available for the production of this amount of power on any of the streams in the eastern bituminous coal region. This fact, however, does not preclude the future development of power capacity with proper regulation of these rivers by storage. On Potomac River hydroelectric developments are contemplated at Great Falls, near Washington, which involve controlling the river flow by means of large reservoirs on the South Branch. When this plan is carried out the stream flow at the proposed site will be adequate for a 300,000-kilowatt steam plant. Coal for such a plant would come largely from the Georges Creek field, with an average haul of about 35 miles.

Ultimately steam-electric power plants may be profitably developed at sites near the bituminous mines, especially after the electrification of railroads has been extended sufficiently to create considerable demand for power within economical transmission distances from these sites.

APPENDIX G.

HYDROELECTRIC PLANTS FOR THE SUPERPOWER SYSTEM.

By L. E. Imlay, L. A. Whitsit, B. J. Peterson, and others of the engineering staff.

THE USE OF HYDROELECTRIC PLANTS.

The installation of hydroelectric plants is justified where the interest on the investment plus the cost of operation amounts to less than that for steam-electric plants, so that the economical proportions of water and steam development must depend upon the cost of money, coal, and labor.

Hydroelectric plants can be classified as of three types, the type depending upon the character of the stream flow, namely:

1. Uniform stream flow by which the output may be maintained for 24 hours a day.

2. Variable stream flow without storage. A hydroelectric plant of this type is especially useful in a large interconnected system, but less so if it supplies a single system, for then the economical use of water is most difficult, if not impossible. The flow curve of such a river is as clearly defined as the load curve of the power market, and evidently power must be wasted unless either the load curve of the market is coincident with the flow of the river or the market load is sufficiently large to absorb the entire hourly output of the plant. It is obvious that the load of a large interconnected system can absorb the hourly output of a plant of this type.

3. Variable stream flow with storage, which provides water for carrying peak loads. The maximum attainable load factor for the superpower system will probably be 50 per cent. With such a load factor 14 per cent of energy (in kilowatt-hours) will carry a 50 per cent peak load (in kilowatts). It is therefore apparent that the value of water storage will lie in the utilization of the stored kilowatt-hours for carrying peak load, inasmuch as, after the dam and head works of the hydroelectric plant have been installed, the investment in generator capacity is but half as much as that for a complete steam-electric plant. In other words, stored water should be held in reserve for peak load.

POTENTIAL HYDROELECTRIC DEVELOPMENTS.

GENERAL CONSIDERATIONS.

The investigation of potential hydroelectric development is limited to the major hydroelectric resources of the superpower zone and to such outside sources of hydroelectric energy as may be reasonably expected to contribute to it. The principal rivers involved are the Potomac, Susquehanna, Delaware, Hudson, Black, Raquette, Connecticut, St. Lawrence, and Niagara. (See Pl. IX.) The Niagara at Niagara Falls contains the largest single potential hydroelectric power development on the North American continent. It is within transmission distance of the superpower zone, but its development beyond what is already provided for is prevented for an indefinite time by international treaty. All the power resources of the zone are not included in these studies, those below 5,000 kilowatts in capacity being disregarded except where contiguous sites of smaller capacity aggregate more than that amount. These small powers will be developed as local conditions warrant, and the plants will be connected to the superpower system through the facilities of the electric public-utility companies. The superpower system will permit the earlier construction of the smaller plants by providing a market for energy not required locally.

U.

The following table gives a general idea of the characteristics that affect the availability of the rivers for power:

TABLE 83.—*Characteristics of rivers that may furnish power in the superpower zone.*

River.	Point of record.	Natural run-off 50 per cent of the time in year of average stream flow (second-feet).	Lowest recorded daily run-off (second-feet).	Possible continuous regulated flow in average year (second-feet).	Total drainage area (square miles).	Fall available for power development (feet).
Potomac	Great Falls [a]	6,500	660	7,650	11,500	215
Susquehanna	Harrisburg	19,500	2,000	.....	24,100	220
Delaware	Port Jervis	3,100	175	4,600	3,100	600
Hudson	Spier Falls	3,000	(b)	4,200	2,800	1,500
Raquette	Piercefield	900	(b)	1,430	723	1,360
Connecticut	Sunderland	8,160	[c] 1,330	.....	8,000	[d] 378
St. Lawrence	Lock 23	235,000	[e] 182,000	.....	285,000	85
Niagara	.....	212,000	170,000	.....	254,700	310

[a] Flow at Great Falls determined from records of flow of Potomac River at Point of Rocks, Md., and Monocacy River near Frederick, Md.
[b] Stream flow affected by operation of power plant.
[c] Mean of low week September, 1894, determined from records of flow at Holyoke. Flow somewhat affected by existing plants.
[d] Net head used in report.
[e] Mean for January, 1898.

All these streams except the St. Lawrence and Niagara rise in the Appalachian Mountains. The fall indicated as available for power development in most of the rivers is but a small fraction of the total fall. The developments proposed are practical.

The following table indicates the hydroelectric power resources that are considered economical for supplying the energy requirements of the superpower zone in 1930:

TABLE 84.—*Hydroelectric power resources for 1930.*

River.	Number of plants.	Primary power (kilowatts).	24-hour power (kilowatt-hours).	Economical development (kilowatts).
Potomac	2	34,500	302,000,000	200,000
Susquehanna	2	18,000	158,000,000	185,000
Delaware	12	82,000	717,000,000	350,000
Hudson	14	68,000	595,000,000	150,000
Connecticut	4	29,000	254,000,000	165,000

The quantity of water available for the production of power at the several sites was determined from stream-flow measurements made by the United States Geological Survey or by the State governments. The period of record used for most of the power estimates was 15 years and extended from October 1, 1904, to September 30, 1919. The power and reservoir sites were located from State reports, reports of private engineers, topographic drawings, and personal investigation by the engineering staff. Stream-flow and power-duration curves for reservoir and power sites were plotted for average and minimum years.

Development of primary power on all the streams under consideration, except the Niagara and St. Lawrence, involves the provision of large storage-reservoir capacity. There must be in addition ample forebay capacity at each power plant for peak-load operation. The construction of hydroelectric plants for base-load operations results in the lowest investment and production cost, and additional capacity for peak-load operation is obtained at about one-half the cost of an equivalent amount of steam-generating capacity.

The developments proposed in the estimates for 1925 and 1930 can be justified only if they are included in an interconnected system, as otherwise their output can not be economically absorbed by the power market.

For the rivers that are not included in the 1921–1930 program estimates are given showing the resources that can be developed in average years, together with the investment and production costs.

At practically all sites where hydroelectric plants are designed for peak-load operation there are considerable periods during each year when there is sufficient water to generate energy in excess of peak-load requirements. At such times the hydroelectric plants will be operated at full capacity, thus saving coal that would otherwise be burned in the steam plants of the system.

The recommended capacity for most of the proposed hydroelectric plants is larger than has been recommended in the past for use with individual electric public-utility systems. This is possible only through the interconnected system, which permits full advantage to be taken of peak-load development and of secondary power from hydroelectric plants.

In estimating the over-all efficiency of hydroelectric plants 80 per cent has been taken as the combined efficiency of turbines, generators, and auxiliary equipment and is applied to the net operating head between forebay and tail race.

POTOMAC RIVER.

The Potomac rises in the mountains of West Virginia and flows into Chesapeake Bay. It is not regulated to any appreciable extent, and the flow at Great Falls ranges from 653 to 248,000 second-feet and averages 11,900 second-feet. The drainage area is 11,500 square miles, and the annual rainfall is between 35 and 40 inches. The fall from Point of Rocks, Md., to tidewater near the boundary line of the District of Columbia is 204 feet, of which 151 feet is below the aqueduct dam at Great Falls, 10.5 miles above the District line.

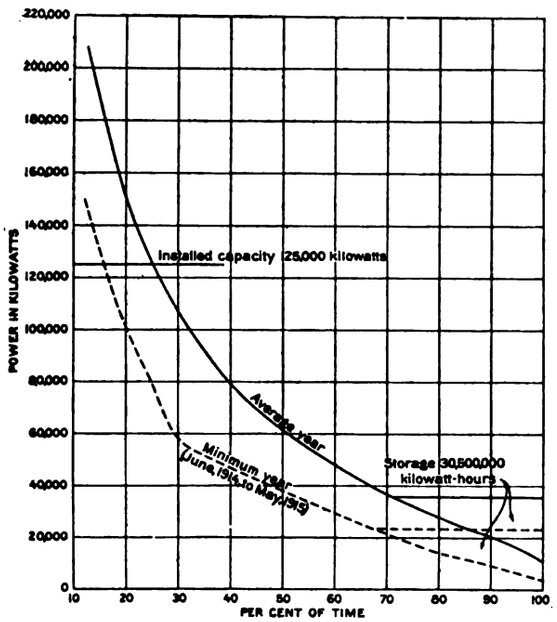


FIGURE 36.—Estimated power available from proposed hydroelectric development of Potomac River for 1925. Total power, average year, 634,000,000 kilowatt-hours; minimum year, 480,000,000 kilowatt-hours. Power site 1 (Pl. IX).

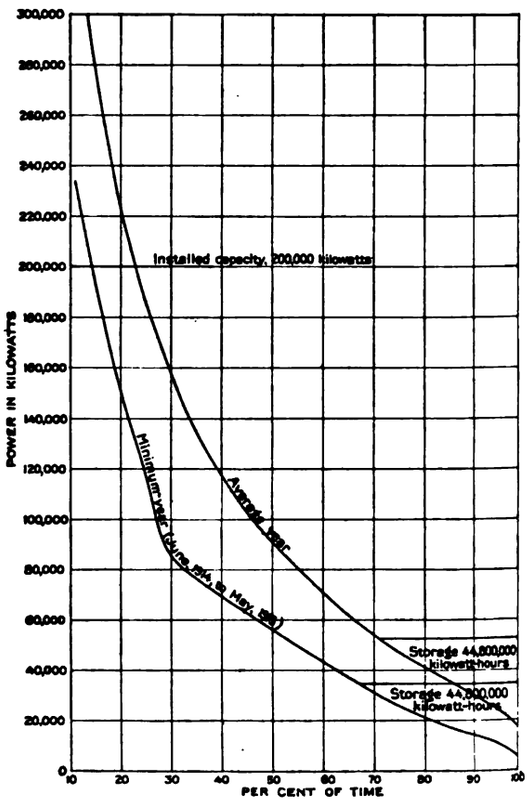


FIGURE 37.—Estimated power available from proposed hydroelectric development of Potomac River for 1930. Total power, average year, 950,000,000 kilowatt-hours; minimum year, 725,000,000 kilowatt-hours. Power sites 1 and 2 (Pl. IX).

There are sites available for storage reservoirs on Great Cacapon River, a tributary stream, where the capacity is 15.6 billion cubic feet; on North Fork of Shenandoah River near Brocks Gap, where the capacity is 4.8 billion cubic feet; farther downstream on Shenandoah River, where the capacity is 11.2 billion feet; and on the South Branch of the Potomac near its junction

with the main river, where the capacity is 20.2 billion cubic feet. Furthermore, the dam at Great Falls will provide a combined storage reservoir and forebay with a capacity of 13.1 billion cubic feet, making a total storage capacity of 65 billion cubic feet.

The most favorable locations for power development are at Great Falls and Chain Bridge, where, by the construction of two dams, a head of 215 feet may be utilized. (For duration of flow expressed in kilowatts at these power sites see figs. 36 and 37.) The following table gives the essential data on this project, which includes the two plants, with necessary reservoir capacity:

TABLE 85.—*Power development on Potomac River.*

	Proposed development.		Possible ultimate development.
	1925	1930	
Reservoir capacity.....billion cubic feet..	13.07	13.07	64.97
Operating head.....feet..	139.5	205	205
Installed generator capacity.....kilowatts..	125,000	200,000	600,000
Output:			
Average year.....kilowatt-hours..	634,000,000	950,000,000	1,370,000,000
Minimum year.....do....	480,000,000	725,000,000	1,030,000,000
Investment cost.....	$15,000,000	$22,000,000	$60,000,000
Annual production cost.....	$2,165,000	$3,190,000	$8,790,000
General expense.....	75,000	110,000	310,000
Total annual cost.....	2,240,000	3,300,000	9,100,000
Time required to complete.....years..	2	2	3

SUSQUEHANNA RIVER.

The Susquehanna has its headwaters in southern New York and in the highlands of northwestern Pennsylvania and empties into Chesapeake Bay. The drainage area above Harrisburg is 24,100 square miles, and the flow at that point ranges from 2,000 to 700,000 second-feet and averages 19,500 second-feet. The average annual rainfall on the area is 40 inches. In the lower 35 miles of the course of the river there is a fall of 220 feet so distributed that most of it may be utilized for power at four points—Conestoga, Holtwood, Conowingo, and a point about 2 miles above Port Deposit. There is already a power plant at Holtwood, which may be advantageously enlarged when the demand for power justifies it. (For duration of flow expressed in second-feet per square mile at Harrisburg, see fig. 38.)

The Susquehanna has no favorable sites for storage reservoirs and therefore must be developed for "run of river" power. Power development at the Conowingo site is hampered by the fact that the railroad parallels the stream just above high-water level, and thus large expenditure would be required for relocating railroad tracks.

The following table gives the data on development of the river at the four points above mentioned:

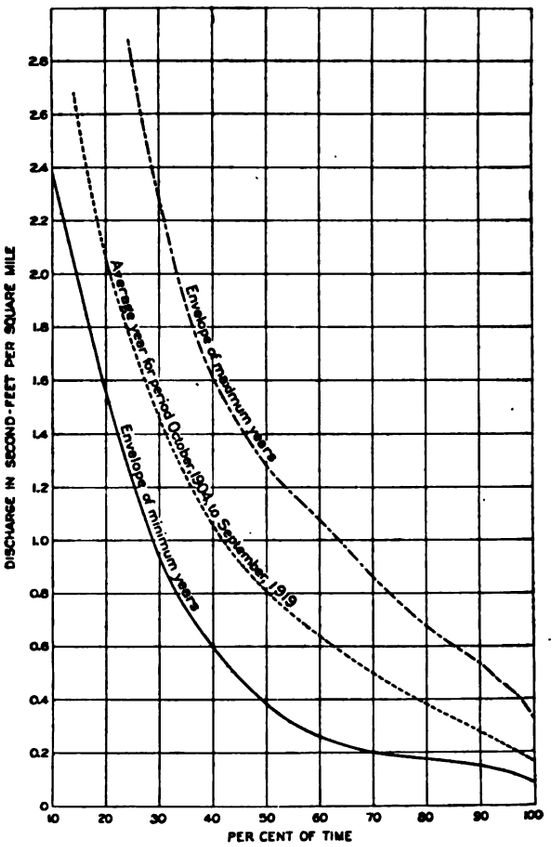


FIGURE 38.—Curves showing duration of flow of Susquehanna River at Harrisburg, Pa. Drainage area, 24,100 square miles.

TABLE 86.—*Power development on Susquehanna River.*

	Proposed development.		Possible ultimate development.
	1925	1930	
Total operating head, including Holtwood.....feet..	131	174	204
Installed new generating capacity.....kilowatts..	120,000	185,000	620,000
Output:			
Average year.....kilowatt-hours..	800,000,000	1,230,000,000	2,700,000,000
Minimum year.....do....	580,000,000	900,000,000	1,850,000,000
Investment cost.....	$18,000,000	$28,000,000	$64,000,000
Annual production cost.....	$2,510,000	$3,961,000	$9,484,568
General expense.....	90,000	139,000	335,432
Total annual cost.....	2,600,000	4,100,000	9,820,000
Time required to complete.....years..	2	2	2

DELAWARE RIVER.

The headwaters of Delaware River are in the Catskill Mountains, and it empties into Delaware Bay. The drainage area above Port Jervis is 3,100 square miles, and the natural stream flow at that point ranged from 175 second-feet in September, 1908, to a maximum of 108,000 second-feet in February, 1909. The average annual rainfall on the area is about 40 inches.

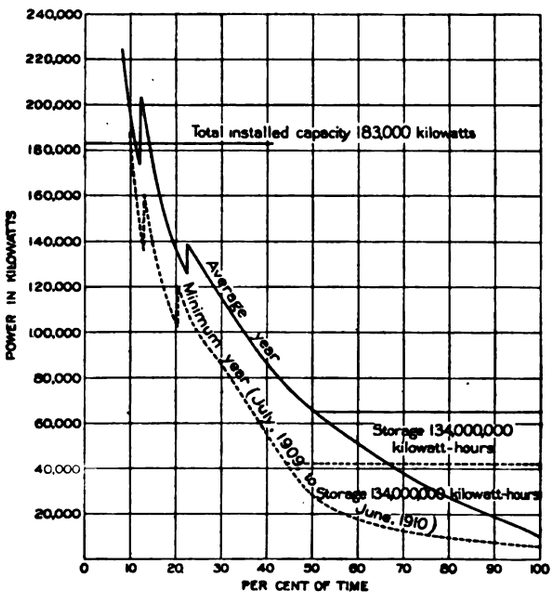


FIGURE 39.—Estimated power available from proposed hydroelectric development of Delaware River for 1925. Total power, average year, 850,000,000 kilowatt-hours; minimum year, 650,000,000 kilowatt-hours. Reservoir A (Pl. IX), 12 billion cubic feet. Power sites 6 (storage 7.5 billion cubic feet), 7, 10, 12, 13, 15, 16 (Pl. IX).

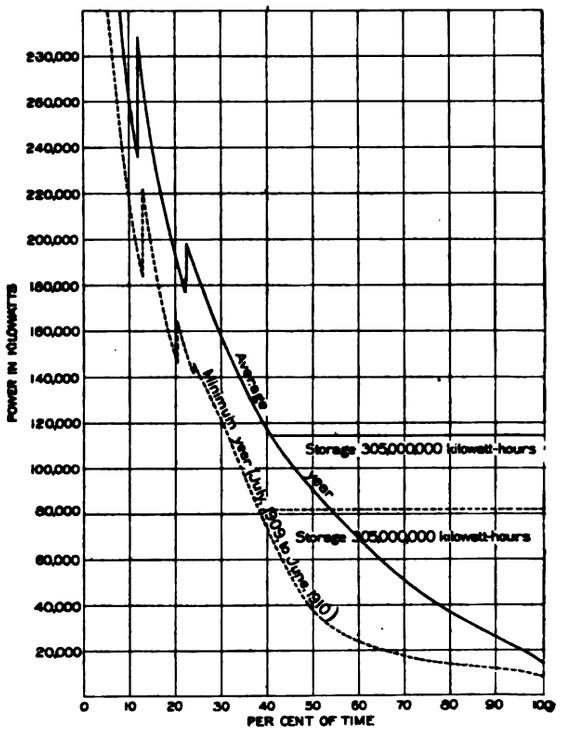


FIGURE 40.—Estimated power available from proposed hydroelectric development of Delaware River for 1930. Total power, average year, 1,250,000,000 kilowatt-hours; minimum year, 1,030,000,000 kilowatt-hours. Reservoirs A (Pl. IX), 12 billion cubic feet; B, 5 billion cubic feet; D, 8 billion cubic feet; E, 3 billion cubic feet. Power sites 1, 2, 4, 5, 6 (storage 7.5 billion cubic feet), 7, 10, 12, 13, 14, 15, 16 (Pl. IX). Total storage 35.5 billion cubic feet.

Between Hancock and Belvidere, a distance of 125 miles, there is a fall of 600 feet. The development proposed is to be effected by means of a series of dams, each of which will back up the water to the next site above. It is proposed ultimately to develop 12 sites on the main river, one on Wallenpaupack Creek, one on Shohola Creek, and one on Mongaup River. On the Delaware also power development is hampered by the presence of railroad tracks along the banks of the stream, but in the proposals for development the height of dams has been restricted

so that only at one site will the grade of the railroad have to be changed. The power plants on the Delaware will be located at the dams, but for those on the three tributary streams tunnels will be required.

Owing to the wide variation in the flow of this river storage reservoirs will be absolutely necessary in its development. There are a number of favorable sites on the east and west branches above Hancock, and also one on each of the tributary streams on which developments are proposed. A capacity of 50 billion cubic feet can be provided in eight reservoirs, which are shown on Plate IX. Practically all the sites have a forebay capacity which will enable the plants to be operated on peak loads at a low capacity factor. (For duration of flow expressed in kilowatts at these power sites see figs. 39 and 40.)

The following table gives the data on development of Delaware River and its tributaries:

TABLE 87.—*Power development on Delaware River.*

	Proposed development.		Possible ultimate development.
	1925	1930	
Reservoir capacity.....billion cubic feet..	19.5	35.5	50.0
Total operating head, Delaware River.....feet..	279	453	471
Head on Wallenpaupack Creek.....do....	280	280	280
Head on Shohola Creek.....do....	.....	.....	580
Head on Mongaup River.....do....	.....	.....	430
Total installed generator capacity.....kilowatts..	183,000	350,000	668,500
Output:			
Average year.....kilowatt-hours..	850,000,000	1,250,000,000	1,490,000,000
Minimum year.....do....	650,000,000	985,000,000	1,210,000,000
Investment cost.....	$25,700,000	$51,500,000	$86,500,000
Annual production cost.....	$3,730,000	$7,450,000	$12,630,000
General expense.....	130,000	260,000	440,000
Total annual cost.....	3,860,000	7,710,000	13,070,000
Time required to complete.....years..	2	2	4

HUDSON RIVER.

Hudson River rises in the Adirondack Mountains and empties into the Atlantic Ocean at New York. The drainage area at Spier Falls is 2,800 square miles and at Troy 8,100 square miles. The stream flow at Spier Falls ranged from 660 second-feet, the mean for the low week in September, 1913, to 84,200 second-feet in March, 1913. The average annual rainfall on the area is about 45 inches. There is a gross fall of 975 feet between Ort Falls and Hadley. A large number of hydroelectric plants have been built on the Hudson, and complete development would involve about 16 new plants and reconstruction or replacement of 14 existing plants. (For duration of flow expressed in kilowatts at these power sites see figs. 41 and 42, p. 198.)

There are four available storage reservoir sites—Lake Piseco, 4.3 billion cubic feet; Sacandaga River at Conklingville, 37 billion cubic feet; Schroon Lake at Alder Brook, 12 billion cubic feet; and Indian River at Bullhead Pond, 10 billion cubic feet; total, 63.3 billion cubic feet.

TABLE 88.—*Power development on Hudson River.*

	Proposed development.		Possible ultimate development.
	1925	1930	
Reservoir capacity.....billion cubic feet..	[a] 10	[a] 10	[a] 63.3
Installed generator capacity.....kilowatts..	100,000	150,000	430,000
Output:			
Average year.....kilowatt-hours..	380,000,000	900,000,000	1,560,000,000
Minimum year.....do....	330,000,000	800,000,000	1,370,000,000
Investment cost.....	$20,124,000	$38,350,000	$74,384,000
Annual production cost.....	$2,815,000	$5,250,000	$10,520,000
General expense.....	99,000	200,000	370,000
Total annual cost.....	2,914,000	5,450,000	10,890,000
Time required to complete.....years..	2	2	3

[a] Gross capacity including present storage of 4.6 billion cubic feet.

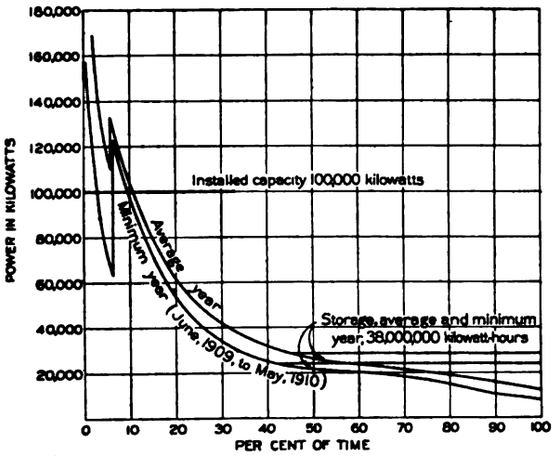


FIGURE 41.—Estimated power available from proposed hydroelectric development of Hudson River for 1925. Total power, average year, 380,000,000 kilowatt-hours; minimum year, 330,000,000 kilowatt-hours. Reservoir A (Pl. IX), net increased storage 5.1 billion cubic feet. Power sites 7, 8, 9, 10, 11 (Pl. IX).

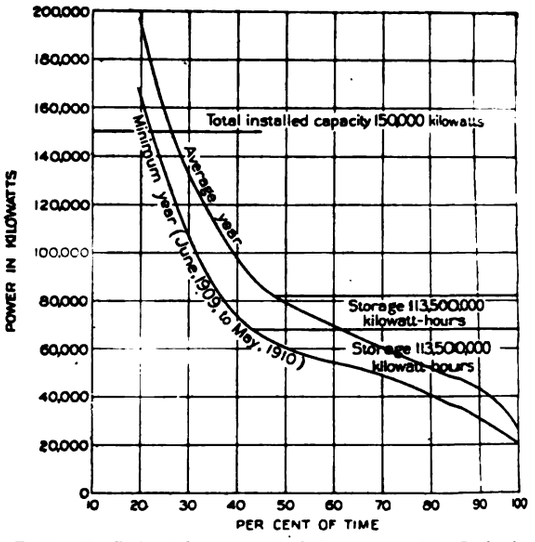


FIGURE 42.—Estimated power available from proposed hydroelectric development of Hudson River for 1930. Total power, average year, 900,000,000 kilowatt-hours; minimum year, 800,000,000 kilowatt-hours. Reservoir A (Pl. IX), net increased storage 5.1 billion cubic feet. Power sites 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 14, 16, 17 (Pl. IX).

RAQUETTE RIVER.

Raquette River rises in the Adirondack Mountains and empties into the St. Lawrence near Cornwall. The drainage area at Raymondsville is 1,070 square miles, and the stream flow at Piercefield ranged from 58 second-feet, the mean for the low two-week period in September, 1913, to 6,970 second-feet in April, 1913. The average annual rainfall on the area is 48 inches. In 72 miles of this river between Piercefield and Raymondsville there is a fall of 1,350 feet.

The drainage area of Raquette River contains a number of natural lakes, which may be developed into storage reservoirs by the construction of dams at their outlets. It is estimated that 16 billion cubic feet of water may be stored in this manner.

The following statement gives the data of development for Raquette River at 15 sites, at some of which reconstruction of existing plants will be required.

TABLE 89.—*Possible ultimate power development on Raquette River.*

Reservoir capacity	billion cubic feet	16.0
Total net head	feet	938
New installed generator capacity	kilowatts	110,000
Net output:		
Average year	kilowatt-hours	800,000,000
Minimum year	do	670,000,000
Investment cost		$26,500,000
Annual production cost		$3,745,000
General expense		130,000
Total annual cost		3,875,000

BLACK RIVER.

Black River rises in the Adirondack Mountains, flows westward, and empties into Lake Ontario near Sacketts Harbor. The drainage area above Felt Mills is 1,851 square miles. The stream flow is affected by artificial regulation and has ranged from 400 second-feet, the mean for the low week, to 32,166 second-feet. The average annual rainfall on the area is about 45 inches. On Black River proper the main fall is one of 480 feet between Dexter and Carthage, a distance of 31 miles. Beaver River, a tributary, has a fall of 1,024 feet in 55 miles, and Moose River, another tributary, has a fall of 1,087 feet in 45 miles.

A large number of small lakes in the Adirondack Mountains form natural storage reservoirs, and it is proposed to improve these at six sites on Black River and its tributaries to provide an ultimate storage capacity of 21.5 billion cubic feet.

There are 33 existing power plants in this drainage basin, most of which are used for making paper pulp. There are 11 undeveloped sites on Black River and its tributaries.

The following statement gives the data on these developments and includes estimates for the reconstruction of such existing plants as may be justified and for increasing the reservoir capacity 20 billion cubic feet.

TABLE 90.—*Possible ultimate power development on Black River.*

Reservoir capacity (including 1.5 billion cubic feet of existing storage),	billion cubic feet..	21.5
New installed generator capacity	kilowatts..	80,000
Output:		
Average year	kilowatt hours..	350,000,000
Minimum year	do....	315,000,000
Total investment cost		$16,500,000
Annual production cost		$2,290,000
General expense		80,000
Total annual cost		2,370,000
Time required to complete	years..	2

CONNECTICUT RIVER.

Connecticut River rises in the Province of Quebec, Canada, and flows into Long Island Sound about 60 miles east of New Haven. The drainage area is 8,000 square miles, and the stream flow at Sunderland, Mass., ranged from 1,330 second-feet, the mean for the low week in September, 1894, to 110,000 second-feet in April, 1895. Between Fifteen Mile Falls, N. H., and

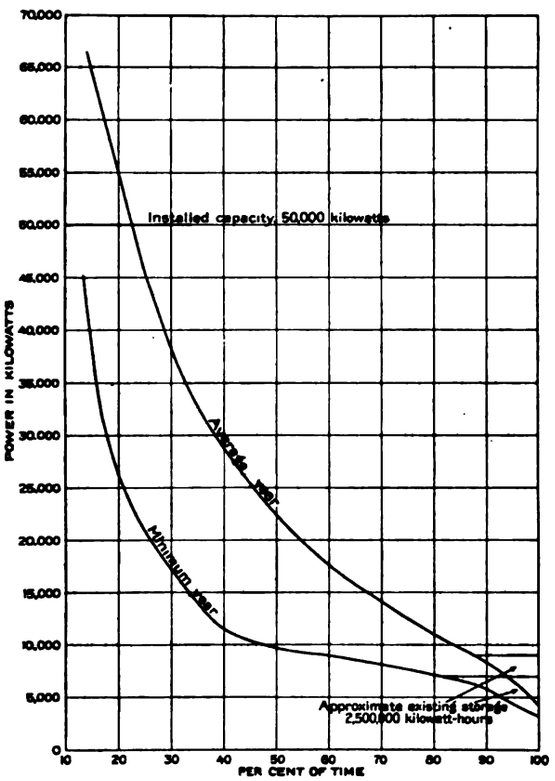


FIGURE 43.—Estimated power available from proposed hydroelectric development of Connecticut River for 1925. Total power, exclusive of storage, average year, 230,000,000 kilowatt-hours; minimum year, 150,000,000 kilowatt-hours. Power site 5 (Pl. IX).

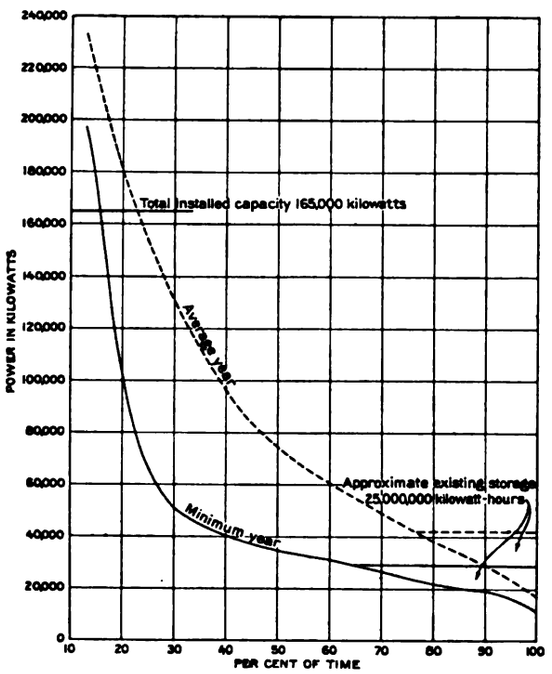


FIGURE 44.—Estimated power available from proposed hydroelectric development of Connecticut River for 1930. Total power, exclusive of storage, average year, 760,000,000 kilowatt-hours; minimum year, 510,000,000 kilowatt-hours. Power sites 1, 3, 4, 5 (Pl. IX).

Windsor Locks, Conn., there is an aggregate usable fall of 428 feet, including redevelopment of the Bellows Falls site but excluding other developed sites. This fall is divided as follows: Fifteen

Mile Falls, 250 feet; Piermont, 50 feet; Quechee Falls, 45 feet; Bellows Falls, 50 feet; Windsor Locks, 33 feet. (For duration of flow expressed in kilowatts at these power sites see figs. 43–45.)

A small amount of storage has been developed and is now used for logging operations and for the development of power. The conditions are favorable for the development of additional storage, which will not only benefit new plants but greatly improve operating conditions at existing plants.

The following table gives data on potential developments at five power sites, which include redevelopment of the Bellows Falls site. The statement does not include additional reservoir capacity:

TABLE 91.—*Power development on Connecticut River.*

	Proposed development.		Possible ultimate development without storage.
	1925	1930	
Total operating head ..... feet	33	428	428
Installed generator capacity ..... kilowatts	50,000	165,000	165,000
Output:			
Average year ..... kilowatt-hours	230,000,000	760,000,000	760,000,000
Minimum year ..... do	150,000,000	510,000,000	510,000,000
Investment cost	$9,000,000	$29,000,000	$29,000,000
Annual production cost	$1,256,000	$4,130,000	$4,130,000
General expense	44,000	140,000	140,000
Total annual cost	1,300,000	4,270,000	4,270,000

ST. LAWRENCE RIVER.

The portion of St. Lawrence River here considered lies between Lake Ontario and a point near Cornwall, where the international boundary diverges from the river in an easterly direction. An investigation is now being made by engineers of the United States and Canadian governments looking to the development of the river in the vicinity of Long Sault and Barnhardts Island. The fall available is about 80 feet, and it is estimated that generating capacity of about 1,200,000 kilowatts can be installed to yield an annual output of more than 10,000,000,000 kilowatt-hours. It is assumed that the ownership of one-half of this output will be allocated to the United States Government. The outstanding feature of this development is that the storage capacity of the Great Lakes, which drain an area of 278,700 square miles, furnishes almost complete regulation of the river flow. The lowest recorded average flow for a month is 186,000 second-feet, which is about 80 per cent of the average continuous flow.

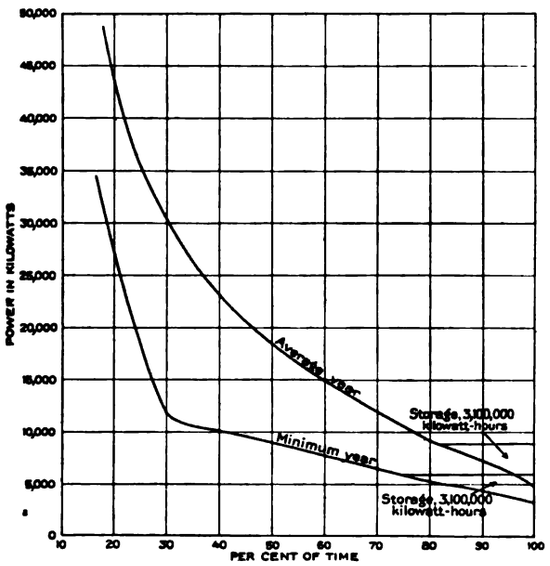


FIGURE 45.—Curves showing duration of power on Connecticut River at Bellows Falls, Vt.

No estimate of the cost of development will be given here, as such an estimate is now being made by the engineers of the two governments. The cost, however, should be lower per unit than that of any of the developments on which estimates are given in this report, on account of the size of the development and because a large portion of the expenditure will be made for the improvement of navigation.

NIAGARA RIVER.

Niagara River is about 30 miles in length and drains Lake Erie into Lake Ontario. The difference in elevation between these two lakes is about 330 feet. The fall between Lake Erie and the river level at the beginning of the rapids above the main falls is 9 feet, between this point and the middle pool below the falls 220 feet, and between the middle pool and Lake Ontario 101 feet. The characteristics of stream flow are much the same as those of the St. Lawrence, but the flow is subject to daily variations due to wind.

The water that can be diverted at Niagara Falls for the generation of power is now limited by international treaty to 20,000 second-feet on the American side of the river and to 36,000 second-feet on the Canadian side. Practically the whole of this permitted diversion has been made, and no further developments are possible so long as the present treaty is in force. It may be abrogated on one year's notice from either party.

The question of additional diversion of water from the river for power is somewhat complicated with the navigation of Lake Erie, as any large increase in diversion will tend to lower the lake level. By the construction of remedial works at the outlet of Lake Erie, however, it will be practicable to increase the amount of water diverted for power without impairing the navigability of the lake. The scenic beauty of the falls may be preserved by constructing works that will distribute the flow more uniformly over the crest. This power would probably be cheaper to develop than St. Lawrence power and would be equally available for use in the superpower zone.

THE RIVERS OF MAINE.

In addition to the resources described above there is considerable undeveloped power in the State of Maine which is within transmission distance of the northeastern part of the superpower zone. As hydroelectric energy generated in Maine can not, under the present laws of that State, be transmitted outside its boundaries, these potential developments have not been analyzed in detail.

The following figures taken from the report of a special water-power investigation by the Public Utilities Commission of Maine for 1918 give an idea of the magnitude of these resources:

TABLE 92.—*Water-power resources of Maine.*

[Horsepower available for 95 per cent of an average year.]

River.	Present conditions.			Conditions after regulation.		
	Developed.	Undeveloped.	Total.	Developed.	Undeveloped.	Total.
Fish	.....	3,600	3,600	.....	6,400	6,400
Allagash	.....	3,600	3,600	.....	8,600	8,600
Presumpscot	5,400	.....	5,400	10,000	.....	10,000
St. Croix	13,000	4,000	17,000	14,000	4,000	18,000
Union	1,600	.....	1,600	5,000	.....	5,000
Kennebec	26,000	50,000	76,000	56,000	105,000	161,000
Saco	11,000	7,000	18,000	24,000	15,000	39,000
Androscoggin	77,800	28,000	105,800	85,000	31,000	115,000
Penobscot	92,000	47,000	139,000	110,000	67,000	177,000
	226,000	143,200	370,000	310,000	237,000	547,000

CAPACITY AND OUTPUT OF EXISTING HYDROELECTRIC PLANTS.

The following table shows the location of hydroelectric generating capacity in operation in the superpower zone and its output for 1919. The table gives an estimate of the capacity that can be furnished for the annual peak under low-water conditions and the annual output for the average and minumum year.

TABLE 93.—*Hydroelectric plants in superpower zone.*

Division.	Installed generator capacity (kilowatts).	1919 output (millions of kilowatt-hours).	Annual peak capacity (kilowatts).	Output (kilowatt-hours).	
				Average year.	Minimum year.
Eastern New England	96,000	292.54	42,835	269,020,000	190,615,000
Western New England	111,530	303.45	51,130	340,015,000	223,650,000
Mohawk	116,150	390.41	45,110	341,450,000	275,020,000
Metropolitan	8,710	24.70	865	22,120,000	14,715,000
Hudson	8,690	22.80	2,415	19,980,000	15,990,000
Anthracite	5,080	17.22	660	16,054,000	12,987,000
Southern	105,340	612.07	53,720	548,790,000	384,630,000
	451,500	1,663.19	196,735	1,557,429,000	1,117,607,000

UNIT AND TOTAL INVESTMENT COST.

The unit investment cost for hydroelectric generating equipment is given in figure 46 for operating heads of 20, 40, 80, 120, and 400 feet and for generating units ranging in size from 5,000 to 30,000 kilowatts. These unit costs are based on prices in the midyear of 1919 and include turbines, generators, low-tension switch gear, wiring erected, interest during construction, superintendence, engineering, and contingent expenses. They are applicable to all units except those first installed, for which 8 per cent must be added to cover development charges. The unit costs were compiled from information furnished by the principal manufacturing companies in this country.

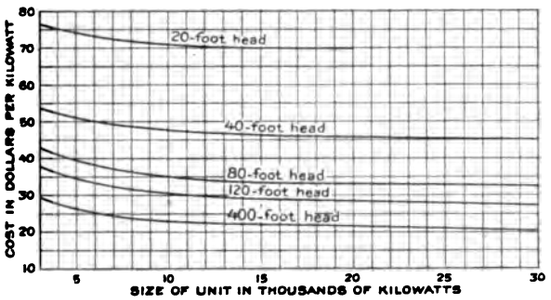


FIGURE 46.—Unit cost for complete hydroelectric equipment installed, for different operating heads in midyear of 1919. Includes turbines, generators, low-tension switch gear and wiring, interest during construction, superintendence, engineering, and contingencies. A development charge of 8 per cent against the first unit should be added.

In estimating the reproduction cost of the existing hydroelectric generating plants as shown below consideration was given to the size of the plant, the operating head, and the other characteristics of individual plants, and the estimates were checked by data furnished by the owners.

Eastern New England	$16,501,000	Hudson	$1,693,000
Western New England	16,713,000	Anthracite	1,265,000
Mohawk	24,442,000	Southern	23,963,000
Metropolitan	2,550,000		87,127,000

ANNUAL OPERATING COST PER UNIT.

In order to determine annual unit operating costs, comprehensive records of 58 hydroelectric plants were selected for analysis. Figure 47 shows the cost per kilowatt-year of total generator capacity plotted against the size of the unit. Figure 48 shows the cost per kilowatt-year of total generator capacity plotted against the capacity of the plant. The use of these two curves in conjunction gives operating cost for power plants employing units of different sizes.

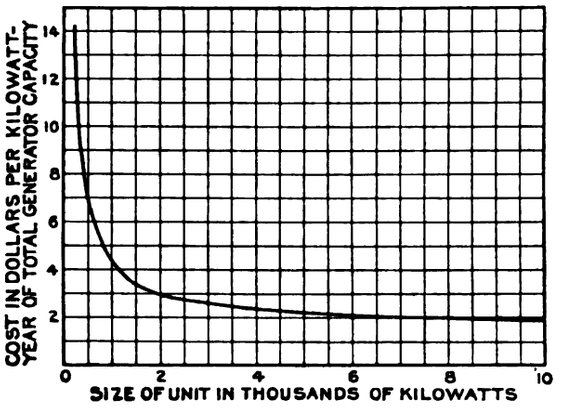


FIGURE 47.—Unit operating cost of 58 selected hydroelectric plants in the superpower zone, 1919, according to size of unit.

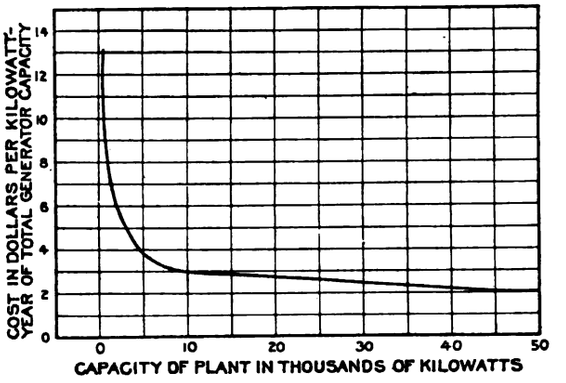


FIGURE 48.—Unit operating cost of 58 selected hydroelectric plants in the superpower zone, 1919, according to capacity of plant.

APPENDIX H.

THE SUPERPOWER TRANSMISSION SYSTEM.

By L. E. Imlay.

EXISTING TRANSMISSION SYSTEMS.

The mileage of the transmission lines above 30,000 volts in the superpower zone in 1919 amounted to 1,200 miles, 37 at 110,000 volts, 813 at 66,000 volts, 36 at 44,000 volts, and 314 at 33,000 volts. Of these 1,200 miles New England has 778, indicating that considerable interconnection has already been established in that region. The high-voltage lines in other parts of the superpower zone are used mainly to transmit energy from sources where it is produced cheaply to points where it is used. The superpower system will multiply these sources of cheap production and will use the existing transmission lines as vehicles of distribution rather than of transmission. Accordingly, the present 33,000 to 66,000 volt transmission systems will be expanded for the distribution of the additional power made available by the superpower system.

CHARACTERISTICS OF THE SUPERPOWER TRANSMISSION SYSTEM.

The proposed transmission lines of the superpower system (see Pls. II, III, p. 14) are of two general classes—interconnecting lines between load centers, operating at 110,000 volts, and high-tension lines of large capacity, operating at 220,000 volts.

INTERCONNECTING LINES.

The interconnecting lines are to be used (1) to transfer energy from one load center to another in order to take care of small increments of growth in demand until additions to local generating plants are justified; (2) to provide means by which reserve capacity at centers of distribution in one part of the system may be made available for use in adjacent centers; (3) to equalize the load between the generating plants of the system or to distribute it among them as economy or policy may direct; (4) to transmit energy from power plants that are not at load centers and that are not provided with separate high-tension lines of transmission.

Any scheme for distributing load between generating centers over tie lines presupposes the automatic operation of governors on prime movers to maintain proper speed under all variations of load up to the full capacity of the generating units. An ideal interconnecting system would function automatically, for when an overload comes on any part of the system the prime mover of that part tends to slow down and lower the frequency, and its slowing down causes the generating units of the part affected to become somewhat out of phase with those of the rest of the system and produces a flow of energy from the lightly loaded to the more heavily loaded part of the system. Owing to physical and economic limitations, however, lines having considerable resistance and reactance can be automatically controlled only within rather narrow limits of load transfer between two load centers several miles apart, so that automatic regulation of voltage is not possible, except through a comparatively small range, without the use of special regulating equipment, for it presupposes a very low reactance circuit with relatively low resistance.

Under ordinary conditions energy may be transferred through a tie line so as to maintain the same bus voltage at all distributing points in a system by varying either the voltage or the impedance volts of the line. The voltage may be varied by shifting to different taps on the transformers, by the use of synchronous boosters, or by the use of some form of regulator. The induction regulator is probably the most satisfactory, and it should be manipulated by hand,

as no device yet contrived can automatically distinguish between a variation due to a short circuit and one due to a change in demand. The impedance volts may be varied by the use of synchronous condensers at the receiving station.

In varying either the voltage or the impedance volts of the tie lines the limitations of synchronizing power and of corona effect should be considered. If a regulator is used a conductor of a size that will insure economy must be selected, and if synchronous condensers are used a design should be selected that will insure regulation rather than prevent loss of power.

If the tie lines are not long and if they are to carry relatively little energy the load can generally be carried by providing lines having low resistance. If the governors and the voltage regulators function properly they will automatically tend to distribute the energy as demanded if the fields in the generators in the station receiving energy are strengthened. If the demand is so great that the capacity to which the generator fields can be strengthened is exhausted before normal voltage is reached the deficiency must be supplied by providing synchronous-condenser capacity.

Consideration has been given to the effect of short circuits that may occur on the network of lines of the superpower system. Obviously, to insure the maximum economy an ideal system should be interconnected and operated as a unit. Studies of the possible concentration of energy resulting from short circuits at critical points in an ideal superpower system indicate, as was expected, that the short-circuit currents would exceed the rupturing capacity of any circuit breaker now available. In planning the interconnecting system contemplated in this report the limitations of the circuit breakers now available and the operating conditions to be provided for have been fully considered. If a short circuit occurs the system will be automatically separated at selected points into several systems that are complete in themselves, in order to limit the energy interrupted to amounts that can be readily handled. The feeders affected by the short circuit are thus automatically disconnected from the system, with minimum disturbance to the service. The rapid improvement in circuit breakers within the last few years leads us to expect that future improvement may produce apparatus that will permit much greater concentration of power, so that by the time the superpower system has grown to a size requiring circuit breakers of larger capacity they will probably be obtainable.

No insuperable difficulty is expected in obtaining rights of way for tie lines in the outlying districts of the superpower zone, where overhead circuits will be used, but rights of way in the congested parts of the large cities, where underground lines operated at comparatively low voltage are necessary, may not be obtained so easily. In New York City, for example, the generating stations are not now sufficiently provided with tie lines to insure the most economical operation on account of the prohibitive cost of conduits or conduit space for high-tension cables. Tie-line connection between New York and the industrial district of New Jersey is still more difficult to obtain and is even more necessary. Particular attention is called to the necessity of providing ample conduit space for tie lines in the new vehicular tunnel under the Hudson between New York and Jersey City.

TRANSMISSION LINES.

The principal elements to be considered in designing transmission lines are length of line, amount of energy to be transmitted, frequency, voltage, corona, resistance, reactance, conductance, susceptance, value of energy lost, cost of money, cost of operation, and value of energy delivered at the receiving end of the line. Kelvin's law is applicable here if the conductors are large enough to escape corona and if the investment in conductors includes the cost of other apparatus, which varies with the sizes of the conductors considered.

Length of line is determined by location of power plant with respect to market for power.

The amount of energy transmitted on a line may be limited either by the size of the generating plant or by the extent of the market. If a power plant is capable of an increase in capacity, the transmission line should have a margin of capacity to cover the increase or should be susceptible of additions at minimum cost.

The maximum practicable potential used for transmission to-day is 220,000 volts, and in the study of transmission to and within the superpower zone this and lower potentials are used.

Corona fixes one of the limits to economical long-distance transmission at very high voltages. There is a critical disruptive voltage for each size of cable, depending on spacing and arrangement of conductors, elevation above sea level, and meteorologic conditions. Rain, fog, and snow tend to lower the critical voltage. Up to 2,000 feet above sea level the minimum diameter of conductors for operation at 110,000 volts is about 0.45 inch and the minimum diameter of conductor for operation at 220,000 volts is about 0.95 inch.

The fundamental characteristics that determine the losses and the performance of a line are resistance, reactance, conductance, and susceptance. Resistance depends upon the size and length of the conductor and the material of which it is composed. Reactance varies with the frequency employed and with the length, size, arrangement, and spacing of the conductors. Conductance varies with the effect of corona and with insulation of line. Susceptance determines the charging current of the line and depends on the spacing, diameter, and arrangement of conductors, the frequency employed, and the length of circuit.

For lines of moderate length, say up to 350 miles, energy can be transmitted at 60 cycles, the prevailing frequency in the superpower zone. For longer lines it may be desirable to transmit at a lower frequency on account of the limitations of reactance and susceptance, but energy for use in the superpower zone will probably never be transmitted farther than 350 miles.

Kelvin's law is applicable to the design of high-tension transmission lines if account is taken of all the factors, which vary with variations in the conductors considered. The effect of these factors is subject to constant change, and the adoption of a particular design can be justified only if the cost of all the elements that may affect it are known. The cost of money, the cost of material, and the value of energy at the receiving end of the line are the principal elements involved.

The structural features of designs of existing transmission lines have been carefully worked out, and the designs for the transmission lines proposed involve no new problems. It may be economical, however, to use a type of tower construction for long lines that is different from the type used for comparatively short lines that transmit the same amounts of energy. For conductors of moderate size to be used under the usual limiting conditions the most economical tower spacing will be as follows: For hard-drawn copper, about 800 feet; for steel-reinforced copper, about 1,000 feet; for steel-reinforced aluminum cable, 1,200 to 1,500 feet.

The principal elements to be considered in spacing towers economically are (1) the character of the cable (weight, tensile strength, elastic limit, and temperature coefficient of linear expansion); (2) the clearance from the ground; (3) the assumed loading by ice and wind pressure; and (4) the cost of towers, foundations, insulators, and labor.

All 110,000 and 220,000 volt systems should be star connected with grounded neutral. The 110,000-volt lines may be provided with overhead ground wires where A-frame construction is used, but the 220,000-volt lines should not be provided with either ground wires or lightning arresters, for they will probably cause more trouble than they will prevent.

The entire superpower zone lies within an area that is occasionally subject to severe sleet storms, and authentic records show that sleet 1½ inches in radial thickness has been formed on line conductors. The cost of building transmission lines to withstand so heavy an accumulation of sleet would be prohibitive. The remedy is to keep the lines so warm during a sleet storm that ice will not collect on them, either by transmitting sufficient energy over them or by short-circuiting them and sending enough current through them at low voltage.

RIGHTS OF WAY.

The importance of adequate rights of way for transmission lines can hardly be overestimated. Many of the troubles on existing long-distance lines are due to crooked lines, which introduce hazardous construction. The service rendered to the public over many power lines is greater than the service rendered by some railroads, and these public lines should have rights of way commensurate with the value of their service. It is therefore an imperative

public necessity that companies operating transmission systems should be granted rights of way through the exercise of the right of eminent domain. A 220,000-volt transmission system consisting of two tower lines, each containing two circuits, should have a right of way 240 feet wide and as straight as it can be made.

Transmission and tie lines should be so located as to avoid interference with service over communication circuits. In anticipation of the necessity of cooperation to avoid such interference conference was had with the engineers of the American Telephone & Telegraph Co., who have furnished the superpower survey a complete set of maps, consisting of 331 topographic sheets, fully indexed, showing the location of the toll lines of that company and its subsidiaries in the superpower zone. The preparation of these maps involved an enormous amount of work by the telephone company, and the set is too large for incorporation in this report, but it may be examined at the office of the United States Geological Survey at Washington.

PERFORMANCE OF TRANSMISSION LINES.

The performance of a transmission line may be determined graphically by the use of vector diagrams indicating currents and voltages at the ends of the circuit and applying the auxiliary constants of the circuit which account for the distribution effect. Figures 49–55 show the performance of a proposed transmission line from St. Lawrence River to a point in central New England. This line will be 225 miles long, will operate at 220,000 volts and 60 cycles, and has been designed to transmit 300,000 kilowatts and supply a distributing system that operates at a power factor of 85 per cent. The transmission system will consist of two tower lines, each supporting two circuits. The conductors are steel-reinforced aluminum cables measuring in cross section 605,000 circular mils and having a diameter of 0.953 inch. Each circuit will transmit 75,000 kilowatts under normal conditions and 150,000 kilowatts in an emergency. Additional data are given on the diagrams.

The diagrams show fully the graphic method of solution and also the mathematical solution. These solutions take into account the leakage and the local impedance of the raising and lowering transformers as well as the effect of these in reducing the effective synchronous-condenser capacity required under load. The mathematical solution given involves the values of the auxiliary constants determined by the employment of hyperbolic functions and is rigorously correct.

Figure 49 shows the conditions existing at no load, with normal load connections and with line and lowering transformers energized. With 220,000 volts at the receiving end of the line, measured at the low-voltage side of lowering transformers, a synchronous-reactor capacity of about 30,000 kilovolt-amperes will be required to hold the voltage at the sending end at 230,000 volts. A synchronous-reactor capacity of about 20,000 kilovolt-amperes will be required to maintain 220,000 volts at both the receiving and the sending ends of the line.

Figure 50 shows the performance of the system at a normal load of 75,000 kilowatts per circuit and 220,000 volts at the receiving end of the line. A synchronous-condenser capacity of about 42,000 kilovolt-amperes will be required to hold the receiving voltage at 220,000 volts with a load having a power factor of 85 per cent. If the voltage at the sending line is held at 220,000 volts the synchronous-condenser capacity required will be about 53,000 kilovolt-amperes.

Figure 51 shows the performance of the system with an emergency load of 150,000 kilowatts on each circuit, a condition that may exist for short intervals while one tower line is out of service for repair. Under these conditions a condenser capacity of 173,000 kilovolt-amperes will be required to hold voltage constant at 220,000 volts at both ends of the line.

Figure 52 shows the amount of energy that may be delivered over this line under various conditions of sending-end voltage to an 85 per cent power-factor load, with 220,000 volts at the receiving end.

Figure 53 shows the synchronous-condenser capacity required for various loads at the three sending-end voltages that are most likely to be used.

Figure 54 shows the voltage on each side of the raising transformers corresponding to condenser loads of various capacities in parallel with a load of 75,000 kilowatts at a power factor of 85 per cent. The vertical distance between the two voltage lines is the voltage drop or voltage rise through the raising transformers. For condenser loads up to 15,000 kilovolt-

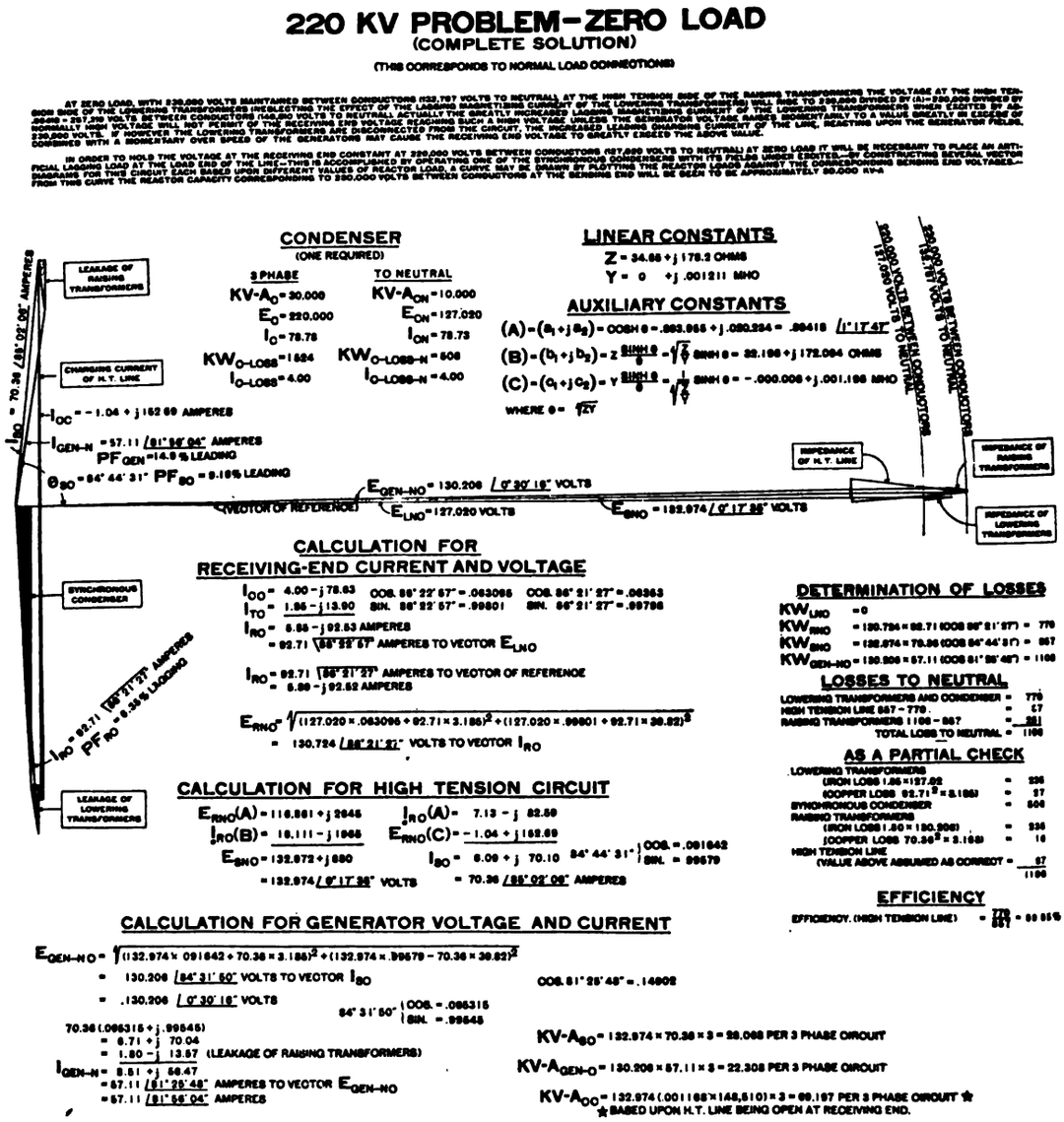


FIGURE 49.—Vector diagram for 225-mile transmission line with no load.

amperes there is a drop in voltage through the raising transformers. For condenser loads above 15,000 kilovolt-amperes there is a rise in voltage through the raising transformers.

Figure 55 is a general diagram showing a possible arrangement of generating, transforming, and transmitting equipment for the St. Lawrence-New England project.

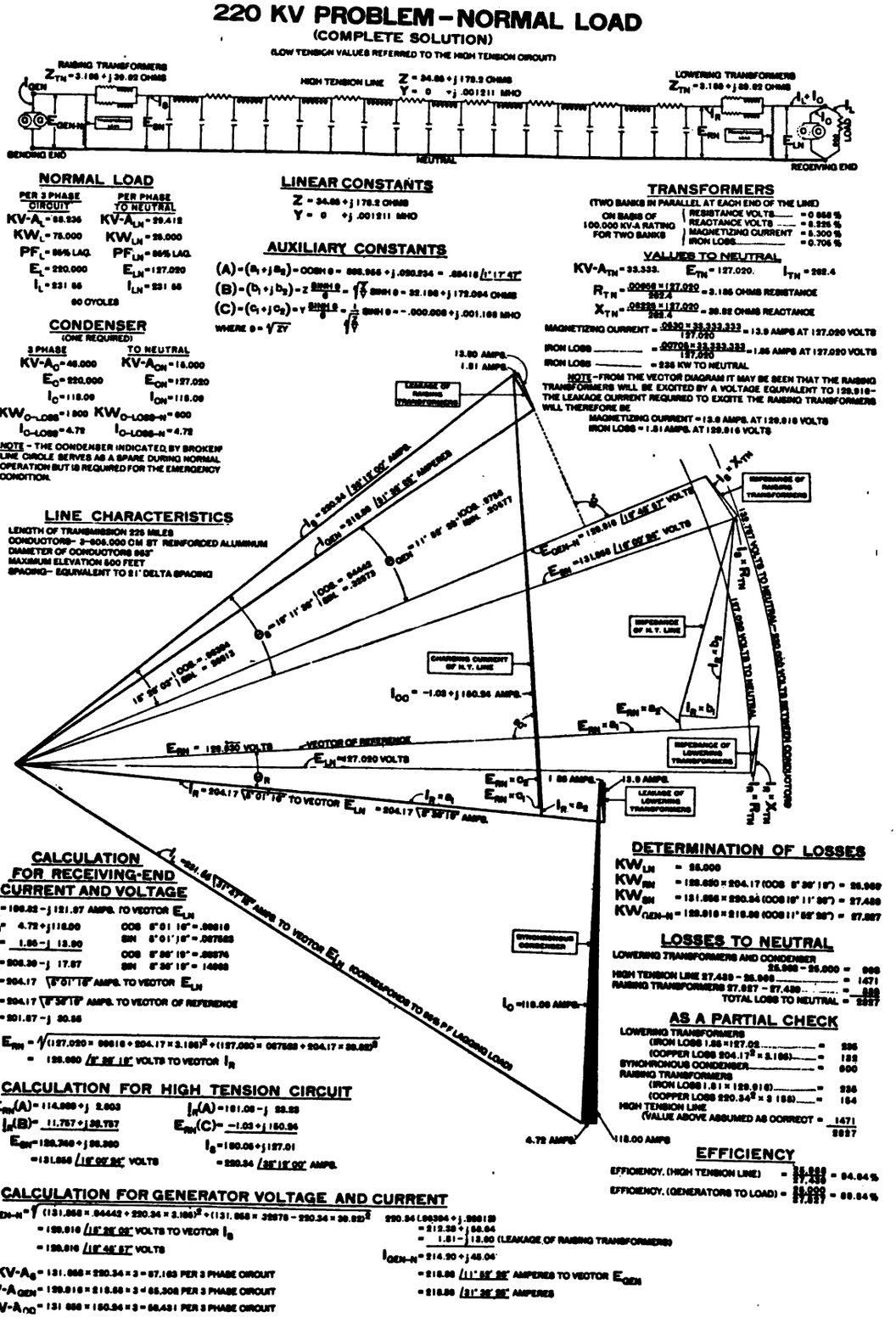


FIGURE 50.—Vector diagram for 225-mile transmission line with normal load of 75,000 kilowatts on each circuit.

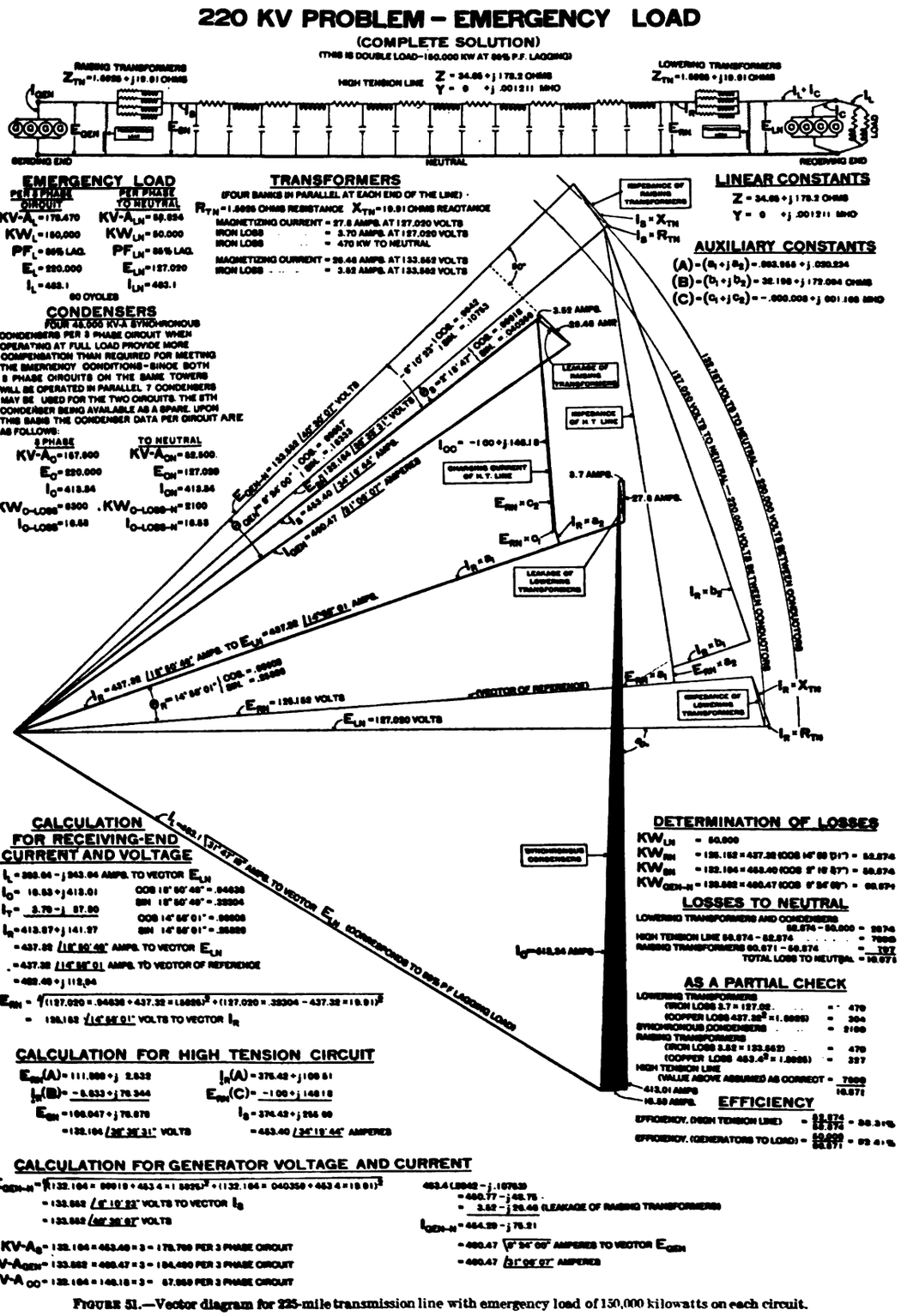


FIGURE 51.—Vector diagram for 225-mile transmission line with emergency load of 150,000 kilowatts on each circuit.

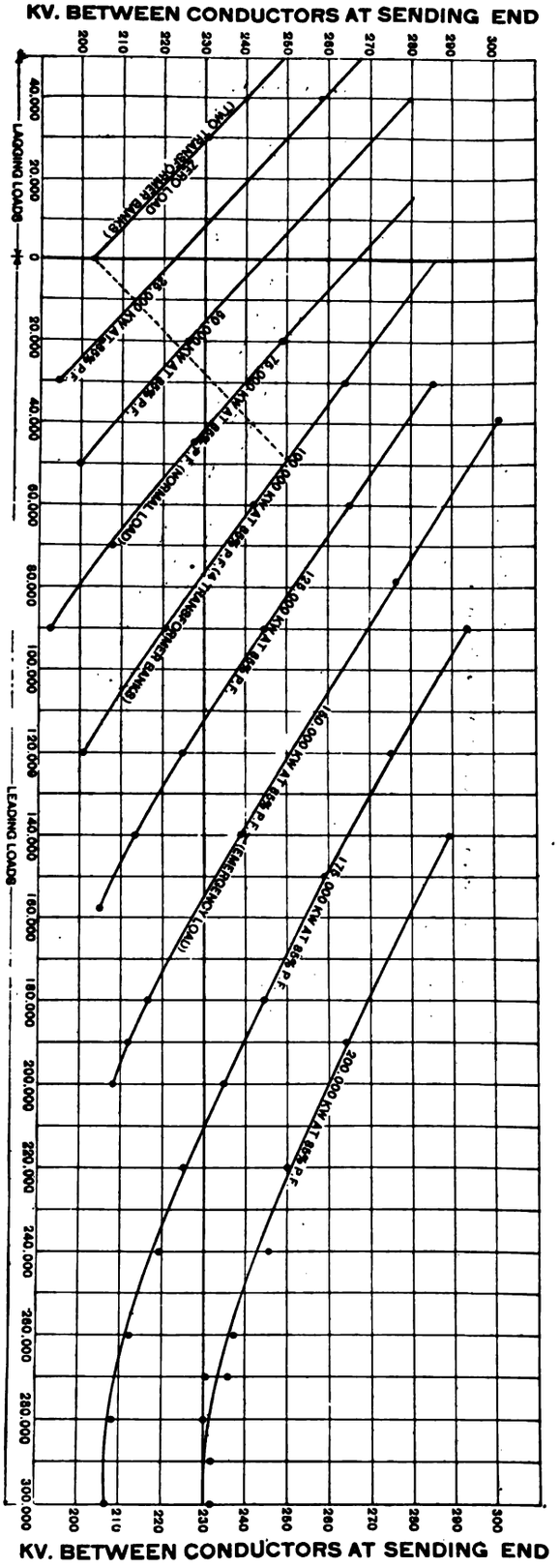


FIGURE 52.—Energy delivered over 225-mile transmission line.

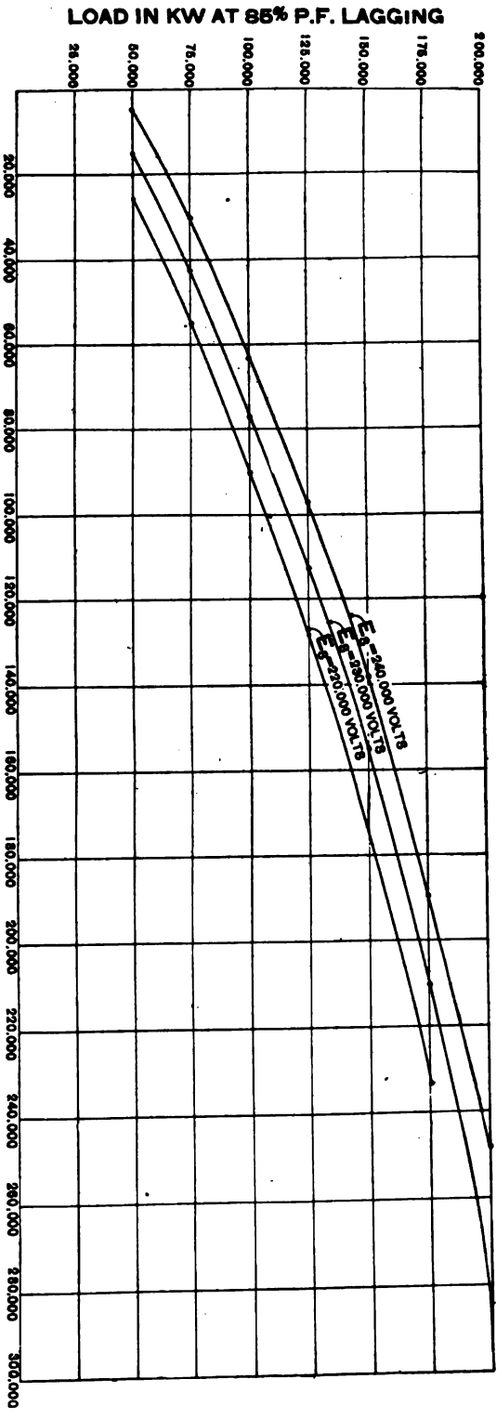


FIGURE 53.—Synchronous-condenser capacity required for 225-mile transmission line.

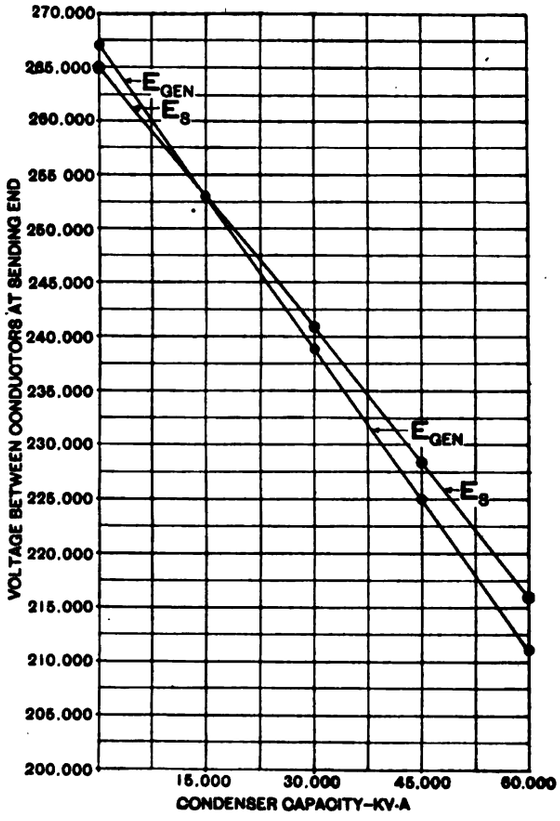


FIGURE 54.—Voltage on raising transformers for 225-mile transmission line.

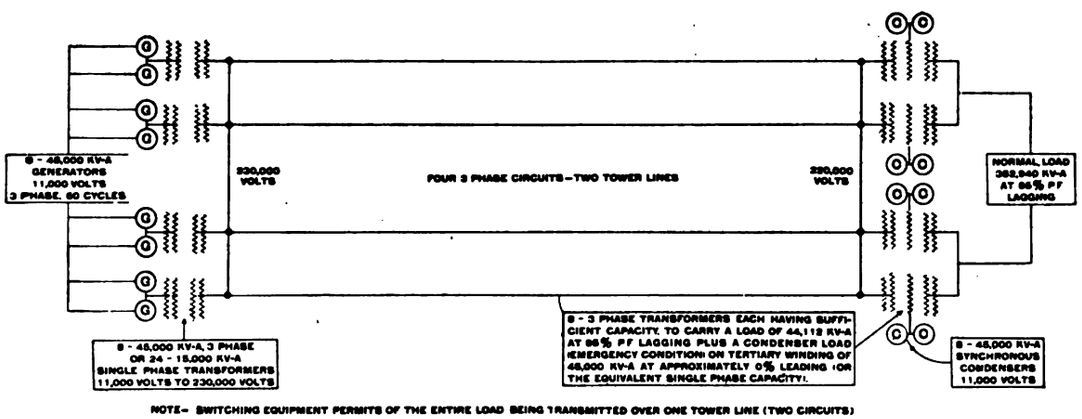


FIGURE 55.—Possible arrangement of equipment for St. Lawrence-New England project.

TABLE 94.—*Character and performance of lines that have been considered as sources of energy for the superpower zone.*

	Niagara Falls-New York line.	St. Lawrence-New England line.	Pittston-Newark line.
Character.			
Energy to be transmitted ... kilowatts	300,000	300,000	300,000
Length of line ... miles	350	225	115
Voltage at generating end	220,000	220,000	230,000
Voltage at receiving end	220,000	200,000	200,000
Frequency ... cycles	60	60	60
Number of tower lines	2	2	2
Number of circuits per tower line	2	2	1
Size of conductor:			
Aluminum ... circular mils	605,000	.....	920,000
Steel ... do	78,000	.....	271,000
Copper ... do	.....	640,000	.....
Normal load per circuit ... kilowatts	75,000	75,000	150,000
Emergency load per circuit ... do	150,000	150,000	300,000
Power factor of load (lagging) ... per cent	85	85	85
Performance under normal load.			
Power factor at sending end of line (leading) ... per cent	88.1	99.5	94.7
Power factor at receiving end of line (lagging) ... do	98.8	96.1	97.6
Synchronous-condenser capacity required ... kilovolt-amperes	180,000	140,000	160,000
Line losses ... kilowatts	28,500	12,500	13,800
Transformer losses ... do	10,500	10,500	10,500
Synchronous-condenser losses ... do	7,200	5,600	6,400
Total losses ... do	46,200	28,600	30,700
Efficiency of transmission ... per cent	86.7	91.3	90.7

COMMUNICATION LINES.

The superpower system can be operated successfully only through absolute unity of operating control. Relations must be established between the different parts of the system to insure unquestioning and immediate response to the directions of some central authority. This requirement involves facilities for instant communication between all the generating and distributing stations. Most of the existing transmission systems provide lines of communication that parallel the lines of transmission and that are supported by the transmission-line towers or by poles erected on the right of way. These lines of communication, supplemented in reserve by the Bell telephone systems for use between important centers, furnish adequate service.

The maintenance of lines of communication on the right of way of a high-tension transmission line that parallels power circuits, where they are particularly exposed to electrostatic and electromagnetic induction, is considered very undesirable by the power company, but it is employed as the surest means of maintaining communication between power plants and distributing stations. The commercial telephone systems have been so greatly improved and augmented that the telephone companies in the superpower zone now have great resources in trunk lines and alternate routes and exceptional facilities for maintaining their plants.

The operation of transmission lines by means of radio telephones or telegraph is being rapidly developed and will probably increase in the near future, particularly as radio communication is free from the effect of interference by high tension circuits.

SUBSTATIONS.

Outdoor substations of standard design, except as the design may be affected by higher voltages, will be used. Synchronous condensers will be installed in the substations to reduce investment and operating cost.

UNIT INVESTMENT COSTS.

TRANSMISSION LINES.

In the following table, showing the unit investment cost per mile for the different types of transmission lines used in existing systems, the cost includes rights of way and is based on prices in midyear of 1919.

TABLE 95.—*Unit investment cost for transmission lines.*

Line voltage.	Conductors.		Number of tower lines.	Total number of circuits.	Cost per mile.
	Material.	Area (circular mils).			
220,000	Aluminum Steel	605,000 78,000	1	2	$27,328
220,000	Aluminum Steel	605,000 78,000	2	4	54,056
220,000	Aluminum Steel	605,000 78,000	1	1	18,760
220,000	Aluminum Steel	605,000 78,000	2	2	36,920
220,000	Aluminum Steel	920,000 212,000	1	1	22,330
220,000	Aluminum Steel	920,000 212,000	2	2	44,060
110,000	Copper	No. 000	1	2	19,160
110,000	do	No. 000	2	4	37,070
110,000	do	350,000	1	1	16,780
110,000	do	350,000	2	2	32,310
110,000	Aluminum Steel	450,000 58,500	1	2	20,945
110,000	Aluminum Steel	450,000 58,500	2	4	40,640
110,000	Aluminum Steel	920,000 212,000	1	2	33,440
110,000	Aluminum Steel	920,000 212,000	2	4	65,630

SUBSTATIONS.

Figure 56 shows the unit cost of 110,000-volt substations with low-tension secondaries in midyear of 1919. This cost includes transformers, structures, and switch gear to accommodate two, four, six, or eight incoming 110,000-volt lines.

Figure 57 shows the unit cost of 220,000-volt substations with low-tension secondaries in midyear of 1919. This cost includes transformers, structures, and switch gear to accommodate two or four incoming 220,000-volt lines.

Figure 58 shows the unit cost of 220,000-volt substations with 110,000-volt secondaries in midyear of 1919. This cost includes transformers, structures, and switch gear to accommodate two, four, or six incoming 220,000-volt circuits and six outgoing 110,000-volt circuits.

SYNCHRONOUS-CONDENSER STATIONS.

Figure 59 shows the unit cost of synchronous-condenser stations at midyear of 1919. This cost includes buildings, synchronous condensers, transformers, and switching and regulating equipment. For the operation of synchronous condensers on 110,000-volt circuits independent transformers are provided; for 220,000-volt circuits a tertiary winding is added to the main transformers.

FREQUENCY-CHANGER STATIONS.

Figure 60 shows the unit cost of frequency-changer stations at midyear of 1919. This cost includes building, frequency changers, transformers, and switching and regulating equipment.

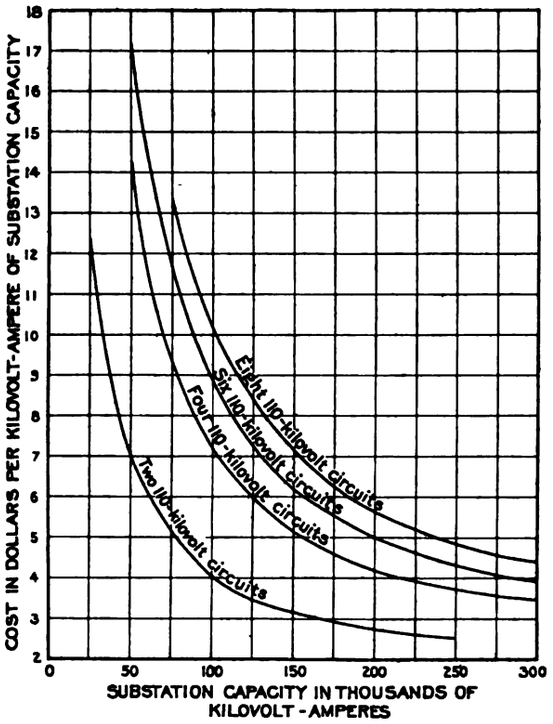


FIGURE 56.—Unit cost of 110,000-volt 60-cycle substations with low-tension secondaries in midyear of 1919.

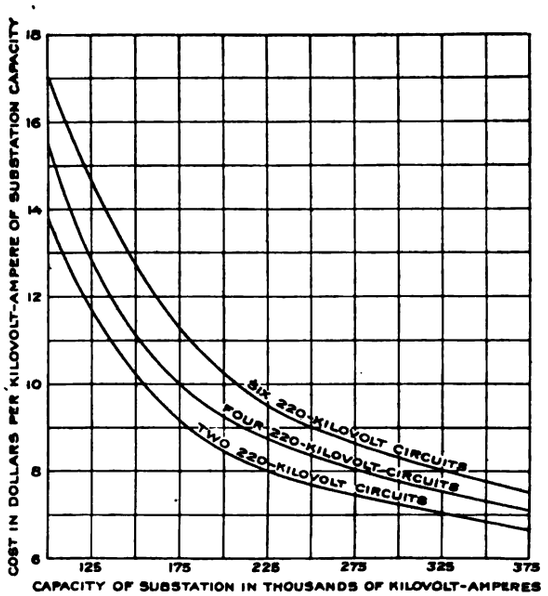


FIGURE 58.—Unit cost of 220,000-volt 60-cycle substations with 110,000-volt secondaries in midyear of 1919.

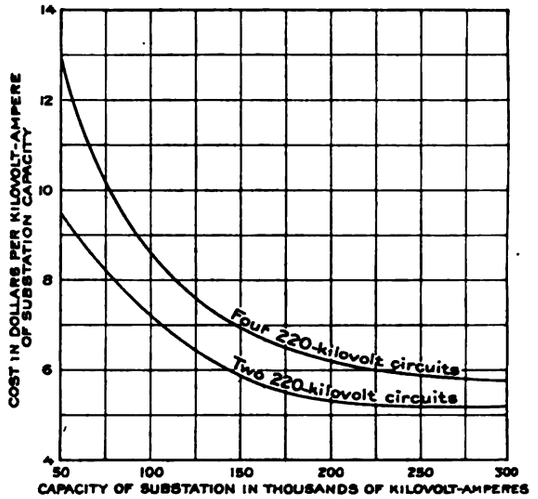


FIGURE 57.—Unit cost of 220,000-volt 60-cycle substations with low-tension secondaries in midyear of 1919.

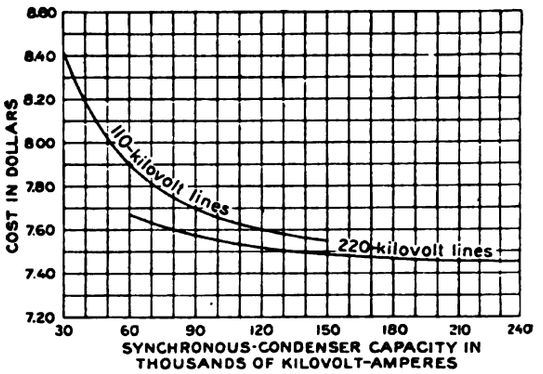


FIGURE 59.—Estimated cost per kilovolt-ampere of capacity of 60-cycle synchronous condensers in midyear of 1919.

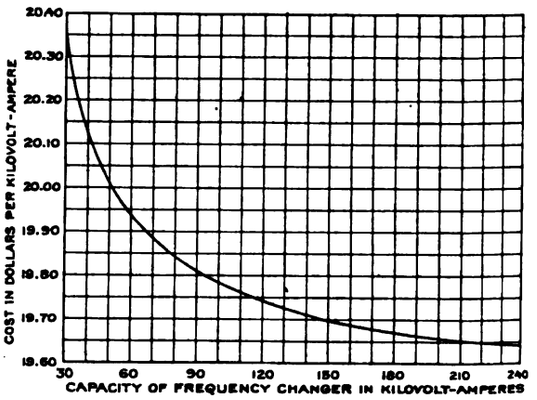


FIGURE 60.—Unit cost of frequency-changer stations in midyear of 1919. Applies to installations of 110,000 or 220,000 volts, 25 or 60 cycles.

OPERATING COST OF TRANSMISSION SYSTEM.

TRANSMISSION LINES.

The following estimated operating cost for transmission lines includes maintenance, labor, and supplies and is based on the actual cost of operating long-distance lines:

TABLE 96.—*Operating cost for transmission lines.*

Line voltage.	Number of tower lines.	Total number of circuits.	Operating cost per mile per year.
220,000	1	1	$175
	1	2	200
	2	2	225
	2	4	250
110,000	1	1	125
	1	2	150
	2	2	200
	2	4	250

SUBSTATIONS.

The annual cost of maintenance and supplies has been fixed at 2 per cent of the total first cost of the substation. For the annual cost of labor $12,000 is used for substations having a capacity of 150,000 kilovolt-amperes or less, $18,000 for those having capacities between 150,000 and 300,000 kilovolt-amperes, and $24,000 for those having capacities of more than 300,000 kilovolt-amperes.

APPENDIX I.

RELIABILITY OF SERVICE.

By L. E. Imlay and others of the engineering staff.

Reliability of service is of first importance. A superpower system with interconnection through many load centers and with provision for obtaining power from several sources can insure continuous service.

Modern power plants, which use large units, are simple compared to power plants built a decade ago. The tendency to locate the plants outside of centers of population has done much to simplify former complicated switching and feeder arrangements.

The principal causes of power-plant interruption, outside of fluctuations in coal supply, are in the coal-handling, boiler, turbine, condenser, and electrical apparatus. Provision is made against such interruptions in the superpower system.

Coal-handling equipment is now provided either in duplicate or of sufficient capacity so that the coal supply will not be in danger of exhaustion. To the popular mind boiler explosions are regarded as one of the greatest dangers to be apprehended in steam plants, but since the advent of the water-tube boiler there is, so far as explosions are concerned, no limitation to the number and capacity of boilers that may be placed in one plant.

Large steam turbines of recent development have excellent records for continuous operation over long periods. It is true that during the World War considerable trouble was experienced with a number of large turbines, but the cause of this particular trouble has been accurately ascertained and eliminated.

The operating records of turbine units in a number of large plants show that these units are available for service more than 90 per cent of the time, and the margin is within the reserve capacity of the plant.

It is difficult in a well-operated plant to justify interruptions from condenser troubles.

Failures in modern electric generators are no longer frequent. The perfection of oil switches and the complete isolation of the phases and reactance applications have resulted in the elimination of the disastrous effects of short circuits.

Superpower transmission will involve capacities of 300,000 kilowatts and maximum distances of 350 miles. Consultation and exhaustive discussion with the principal transmission authorities of this country regarding a proper support and circuit arrangement led to the conclusion that these transmission systems should consist of two tower lines, each supporting two circuits and each tower line being capable of transmitting the entire load.

Load centers in the past have usually been dependent upon a single transmission line. By virtue of its interconnecting network the superpower system will eliminate the hazard of interruption or disaster from the use of a single line.

The transmission systems for the superpower system will be of entirely different dimensions from those to which we have become accustomed. Appendix H–2 brings out the features of their construction. Their reliability will be of the same order as that prevailing within the best modern power plants. They can thus be considered as merely high-tension extensions of the power-plant busses.

The inherent characteristic of the superpower system, therefore, is adequate provision for reserves through its entire structure.

APPENDIX J.

THE RELATION OF COAL AND COAL-DELIVERY ROUTES TO THE SUPERPOWER SYSTEM.

By C. E. Lesher, F. G. Tryon, and others.

DISTRIBUTION AND USE OF COAL IN THE SUPERPOWER ZONE IN 1919.

Table 97 shows that the coal used by central stations is only about 9 per cent of the total used in the superpower zone; that used for locomotive fuel and other railroad purposes and by industries, mines, Government institutions, waterworks, and the central stations amounts to nearly 71 per cent of the total.

Table 97.—*Distribution and use of coal in superpower zone for 1919, in short tons.*

	Bituminous.	Anthracite.	Total.
Sources:			
Mined in zone	None.	87,607,000	87,607,000
Shipped into zone for consumption therein or for bunker and sea-borne export:			
Imports by water from Canada	3,000	None.	3,000
By rail from United States	70,706,000	143,000	70,849,000
Coastwise from Hampton Roads	7,000,000	None.	7,000,000
Total coal available	77,709,000	87,750,000	165,459,000
Used in zone:			
Railroads:			
Locomotive fuel, class 1 roads	15,640,000	2,765,000	18,405,000
All other railroad supply coal except coal for repair shops, including coal for heating stations and all coal for roads other than class 1	1,830,000	1,880,000	3,710,000
Central electric stations	9,976,000	1,830,000	11,806,000
Industries, mines, and Government institutions	34,669,000	23,419,000	58,088,000
Waterworks	260,000	291,000	551,000
Heating residences and all other buildings not elsewhere specified. Includes coal burned in dwellings, apartment houses, hotels, restaurants, theaters, office buildings, schools, hospitals, churches, public buildings, and State, county, and municipal institutions	4,600,000	34,459,000	39,059,000
Total used in zone	66,975,000	64,644,000	131,619,000
Shipped out of zone:			
Foreign bunker	4,669,000	None.	4,669,000
Domestic bunker, including bunker for Army transports and Navy	2,970,000	None.	2,970,000
Sea-borne exports	3,095,000	152,000	3,247,000
Coal mined in zone but shipped by rail out of zone	None.	22,954,000	22,954,000
Total coal leaving zone	10,734,000	23,106,000	33,840,000

COAL DISTRICTS AND COAL DELIVERY ROUTES.

The bituminous-coal districts tributary to the superpower zone are the Clearfield, Somerset, Windber, Greensburg, Westmoreland, Pittsburgh, Fairmont, Georges Creek, Pocahontas, New River, and Kanawha.

The Clearfield, Somerset, and Windber districts lie nearest, and the freight rate from them is the lowest, but they are within the thin-seam regions, where the production cost is high.

The Westmoreland, Greensburg, Pittsburgh, and Fairmont districts are in the thicker-seam region, where production costs are lower, but the freight rates from them are higher.

About half of New England's coal has heretofore been supplied from the Pocahontas, New River, and Kanawha districts. These districts are the chief sources of coal for export, and when the export demand is large the demand in New England must compete with it.

The selection of sites for base-load steam-electric plants is dependent upon the availability of sufficient condensing water, the cost of coal delivered, and the relation of the plant site to the coal-delivery routes from the mines.

Power plants at tidewater in New England east of New London have a reliable coal supply, as they can obtain fuel from the greatest number of sources, having the option of either all-rail or rail and water delivery. The two particular difficulties in the free movement of coal to New England are congestion at times at the Hudson River gateways, due to weather and traffic conditions, and the shortage of bottoms at certain periods for the movement of coal from Baltimore, Philadelphia, and Hampton Roads to eastern New England ports.

The principal bituminous-coal carriers to the superpower zone are the Pennsylvania, the Baltimore & Ohio, the New York Central, and the Western Maryland. These railroads are also the principal carriers of all other traffic to that zone, and at times the traffic demand exceeds their capacity. At certain points on these lines, such as the classification yards at Cumberland, Altoona, Williamsport, and Harrisburg, congestion has occurred through either the traffic conditions or the topographic conditions; at others congestion is due primarily to the necessity of transfer between the railroads, as at Troy, Albany, Maybrook, and Harlem River.

Plants on Hudson River as far north as Troy can readily receive coal, either through Albany or by river barges from New York Harbor. Between New York and Washington there are a number of good locations for steam-electric power plants. Sites are available along New York Bay, Hackensack River, Passaic River, Raritan Bay, Raritan River, Delaware River as far north as Trenton, Delaware Bay, Chesapeake Bay, and Potomac River as far west as Cumberland. In the inland region Susquehanna River and its branches offer excellent sites for the location of base-load steam-electric plants.

The principal difficulty in the location of steam-electric plants in the bituminous mining districts comes from lack of condensing water. (See Appendix F.)

Plate X shows the location of available coal-mining districts, principal rail routes, and location of base-load steam-electric plants for 1930. Anthracite is not discussed at this time, for plants constructed to burn anthracite will be located in the mining region, and rail delivery will consist only in gathering the coal for them. Power can be delivered to the Newark and Philadelphia load centers from plants to be constructed in the anthracite region more cheaply than power can be generated at these centers. (See Appendix F.)

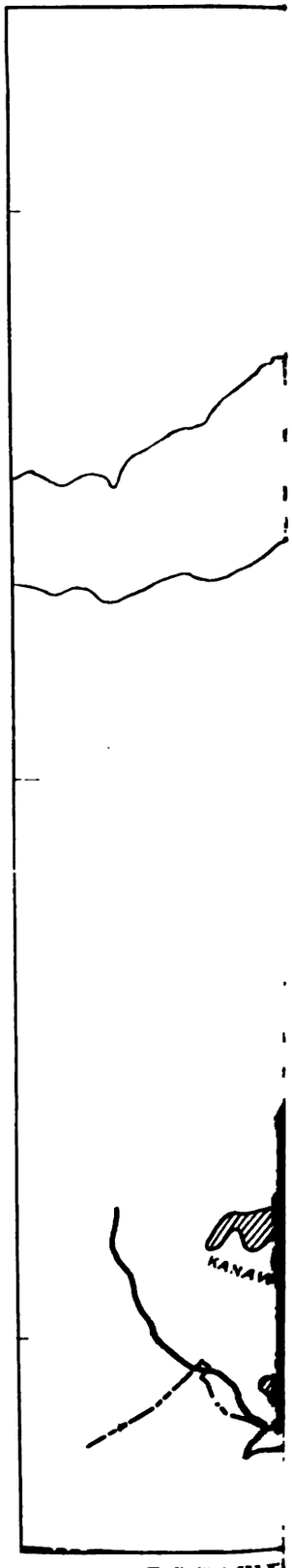
COST OF COAL.

COST OF COAL AT THE MINES.

Bituminous coal.—The average price for bituminous coal at the mine has been taken at $2.90 per short ton for the three years considered (1919, 1925, and 1930) and was determined by the weighted average cost of bituminous coal for 1919 to the fuel-using industries in the superpower zone. This price applies to fuels that take the Clearfield freight rate. The Greensburg, Westmoreland, Pittsburgh, and Fairmont districts, which ship coal to the superpower zone by rail and water, as well as by all-rail routes, sell at a price about 50 cents a short ton lower than the Clearfield district. The Pocahontas, New River, and Kanawha fields supply large amounts of coal to eastern New England by boat, delivered from Hampton Roads. This coal commands a premium of about 50 cents a short ton at the mine over that of the Clearfield district.

Although the cost of labor may be reduced by modification of the present wage scale, which terminates in 1922, the cost of coal tends to increase gradually from the necessity of developing mines in thinner seams and deeper veins and of extending underground haulage in existing mines.

Anthracite.—The price for buckwheat No. 3 coal at the mines has been taken at $1.75 per long ton for the three years considered (1919, 1925 and 1930). This price is based on records of sales made in 1919 and on the competitive relation between anthracite and bituminous coal at tidewater delivery points.



LOCATI

Between 1911 and 1917 the ratio of the cost of buckwheat No. 3 coal at New York Harbor to the cost of low-volatile bituminous coal increased from 53 to 56 per cent. In 1918 it jumped to about 67 per cent, but in 1919 it fell to 66 per cent. The large increase in 1918 and 1919 was due to the fact that bituminous coal was then under governmental regulation, while buckwheat No. 3 coal was not, and it was further due to the difficulty of obtaining deliveries of bituminous coal. The New York Harbor price of buckwheat No. 3 coal has been taken at approximately 63 per cent of the price of low-volatile bituminous. Although this ratio is somewhat higher than that in existence before the war, it is considered reasonable, as the demand for buckwheat No. 3 coal has increased through the development of anthracite stokers and better knowledge of the use of this coal gained during the war.

United States Geological Survey records show that 78,501,931 long tons of anthracite was mined in 1919. Of this total 67,817,284 tons was shipped out of the anthracite district and 8,576,850 tons was used for fuel by the mines themselves. Local sales account for the remainder. The total quantity of buckwheat No. 3 and smaller sizes of anthracite shipped in 1919 was 3,759,000 tons.

Large base-load steam-electric plants located in the anthracite region will require approximately 1,600,000 long tons of buckwheat No. 3 and smaller sizes of anthracite for each 300,000-kilowatt plant, which is nearly one-half of the total of those sizes shipped in 1919. However, a large proportion of the mines that now have their own steam plants would be electrified when such power plants were constructed, thus releasing, owing to the higher efficiency of the power plants, a larger amount of the small steam sizes than would be required for the operation of these base-load plants. Under such conditions the demand will not be in excess of the supply. (See Appendix F.)

COST OF COAL DELIVERED TO THE STEAM-ELECTRIC PLANTS.

The cost of fuel at the power plants has been determined by the cost of coal from the Clearfield district.

Coal from the Westmoreland, Greensburg, Pittsburgh, and Fairmont districts costs 50 cents a short ton less than Clearfield coal but is lower in calorific value. Coal from the Pocahontas, New River, and Kanawha fields has a higher calorific value than that of Clearfield, but its mine price is 50 cents a short ton higher. When all charges to the destination point are considered, the number of British thermal units obtained for each dollar expended is nearly the same for coal from all the fields, and the use of the Clearfield prices and freight rates as a basis both for fuel cost and plant performance gives a representative average.

The current freight rates of 1919 are used in the calculations for that year and those existing on January 1, 1921, for the 1925–1930 period.

Table 98 gives the cost of bituminous coal at specified destination points from those fields that are tributary to them.

TABLE 98.—*Cost of bituminous coal per short ton at destination points in the superpower zone.*

Load center.	Mining district.	Period.	Price at mines.	Freight, taxes, insurance, and seasonal coal storage.	Total cost in plant bunkers.
Boston	Clearfield	1919	$2.90	$3.16	$6.06
	do	1925–1930	2.90	4.45	7.35
	Fairmont	1925–1930	2.45	4.68	7.13
	Pocahontas	1925–1930	3.35	5.40	8.75
Providence	Clearfield	1919	2.90	3.24	6.14
	do	1925–1930	2.90	4.59	7.49
	Fairmont	1925–1930	2.45	4.81	7.26
	Pocahontas	1925–1930	3.35	5.15	8.50
New London	Clearfield	1919	2.90	2.79	5.69
	do	1925–1930	2.90	3.93	6.83
	Fairmont	1925–1930	2.45	4.16	6.61
	Pocahontas	1925–1930	3.35	5.40	8.75

TABLE 98.—*Cost of bituminous coal per short ton at destination points in the superpower zone*—Continued.

Load center.	Mining district.	Period.	Price at mines.	Freight, taxes, insurance, and seasonal coal storage.	Total cost in plant bunkers.
New Haven	Clearfield	1919	$2.90	$2.68	$5.58
	do	1925–1930	2.90	3.81	6.71
	Fairmont	1925–1930	2.45	4.18	6.63
Hartford	Clearfield	1919	2.90	3.06	5.96
	do	1925–1930	2.90	4.33	7.23
	Fairmont	1925–1930	2.45	4.55	7.00
Northampton	Clearfield	1919	2.90	3.42	6.32
	do	1925–1930	2.90	4.83	7.73
	Fairmont	1925–1930	2.45	5.07	7.52
Albany and Poughkeepsie	Clearfield	1919	2.90	2.42	5.32
	do	1925–1930	2.90	3.43	6.33
	Fairmont	1925–1930	2.45	3.80	6.25
New York, Newark, and New Brunswick.	Clearfield	1919	2.90	2.32	5.22
	do	1925–1930	2.90	3.35	6.25
	Fairmont	1925–1930	2.45	3.66	6.11
Trenton	Clearfield	1919	2.90	2.23	5.13
	do	1925–1930	2.90	3.17	6.07
	Fairmont	1925–1930	2.45	3.40	5.85
Harrisburg	Clearfield	1919	2.90	1.77	4.67
	do	1925–1930	2.90	2.53	5.43
	Fairmont	1925–1930	2.45	2.77	5.22
Philadelphia, Wilmington, Baltimore, and Washington.	Clearfield	1919	2.90	2.15	5.05
	do	1925–1930	2.90	3.05	5.95
	Fairmont	1925–1930	2.45	3.27	4.72

OWNERSHIP OF COAL MINES.

No advantage has been found in the ownership of coal mines by the power company to offset the elimination of the flexibility of supply, the increase in initial investment, the additional administrative cost, and the hazard common to mining enterprises.

COAL STORAGE.

A 360,000-kilowatt plant at an annual capacity factor of 60 per cent will use 1,260,000 short tons of bituminous coal a year. Storage of six months' coal supply for such a plant will therefore require 630,000 tons. Coal storage in this amount might appear excessive, but the following advantages are evident: (1) It would absolutely prevent interruption of service due to lack of fuel. (2) It would permit the purchase of coal at the lowest market price. Where facilities for coal storage are scanty, the purchase of coal in the spot market at times of shortage and without regard to quality results in an excessive expense, which would more than offset the cost of adequate storage facilities. (3) It would effect partial stabilization of the mining and the transportation industries through bringing about a more uniform demand for fuel and thus tending to increase the operating load factor of these two industries. It is equally obvious that this would be a step toward reducing the price of fuel to the consumer because it would be a step in the reduction of cost of mining and transportation.

There has been some discussion with regard to the ownership by the superpower system of either coal cars or railroad routes or both, but it has been concluded that the superpower system should confine its activities to the production of power and the storage of coal.

The cost of coal storage is included in the production cost of the superpower system.

APPENDIX K.

USE OF PROCESS FUELS AND PULVERIZED COAL FOR BASE-LOAD STEAM-ELECTRIC PLANTS.

By O. P. Hood and others of the engineering staff.

CONCLUSIONS RELATIVE TO THE USE OF PROCESS FUELS.

In considering the use of process fuels by base-load steam-electric stations it has been necessary to fix certain limitations to the study, which must necessarily be a general one covering the entire superpower zone. The study was therefore confined to processes that had reached the stage of commercial development. The fixed charges against the investment cost in the by-product plants have invariably been taken at 20 per cent—10 per cent for the cost of money, 8 per cent for depreciation and obsolescence, and 2 per cent for taxes and insurance. At the same time the operating costs have been taken at $1.35 per ton of coal carbonized, and the prices credited for by-products are those given below.

In a base-load steam-electric plant under present conditions coal must generally be used in the raw form in order to produce cheap power. Local conditions will justify certain exceptions to this practice. At large centers of population it may be found profitable to install process-fuel plants in conjunction with base-load steam-electric stations if the gas produced by the plants can be sold at a profit, particularly where a process is used that will yield gas which has a very high heating value and which can be used to enrich water gas made by the gas companies.

Coal is subjected to a preliminary process for two purposes—to place its energy in a more desirable form and to recover valuable products. If power is produced by the use of either coke or gas from process-fuel plants the value of the remaining products, when credited to the cost of such fuels, is not sufficient to reduce the cost below that of raw coal. As certain by-products are essential in time of war regardless of cost, however, it is desirable in selecting a site for a superpower plant to provide space for a processing plant.

Accordingly, provision is made in the estimated costs for base-load steam-electric plants both for the location of process-fuel plants and for boiler-room construction that will permit the use of process fuel at a later date if it is found advisable.

SOURCES OF PROCESS FUELS.

Four sources of process fuels for base-load steam-electric plants have been considered—by-product coke-oven plants furnishing coke, by-product coke-oven plants furnishing gas, low-temperature distillation plants furnishing semicarbocoal, and bituminous gas producers furnishing gas.

The credits used for by-products are as follows:

Gas, 30 cents per thousand cubic feet.
Tar, 4 cents per gallon.
Light oils, 15 cents per gallon.
Ammonium sulphate, 2½ cents per pound.
Coke, including breeze, $10 per short ton.

The base-load steam-electric plants for which process fuel will be furnished are assumed to be 300,000-kilowatt plants having an annual capacity factor of 70 per cent. Sufficient process-fuel plant capacity must be provided to meet variations in the load of the steam-electric plants.

The average cost of gas coal for carbonization is taken at $6.11 per short ton; the cost of Clearfield coal used directly in the power plant is taken at $6.25 per short ton.

For process-fuel plants the unit operating cost exclusive of fuel has been placed at $1.35 per short ton of coal carbonized, and the fixed charges have been taken at 20 per cent.

Table 99 gives the result of this study. With the exception of gas from by-product coke-oven plants, process fuel is shown to cost more than coal. Moreover, the heavy investment required for a coke-oven plant producing gas as the process fuel, combined with the transportation difficulties in distributing the by-products, makes its use as a source of process fuel impracticable. The coke produced by one such plant would amount to 26 per cent of the total present coke requirement of the superpower zone, and even if the existing coke-producing facilities in the zone are ignored, it would require only four plants of this size to satisfy the entire coke demand of the zone. Furthermore, over 760 special railroad cars daily would be required to distribute the coke output of one such plant to its market and at the same time about 590 cars additional to bring the coal to the plant. Compared to this, only about 70 cars a day would be needed to convey coal to the 300,000-kilowatt steam-electric plant burning raw coal.

For low-temperature distillation plants the by-products have been credited at $4.22 per short ton of coal carbonized, which is 28 cents less than the credits claimed by the Carbo Coal Co., but this difference is immaterial, because to make this process profitable under present conditions more than $5.15 per short ton of coal carbonized must be realized from the by-products. Although the carbocoal process has been selected for analysis, as it is further advanced technically than any of the other low-temperature distillation processes, semicarbocoal has not yet been used extensively in large power plants.

It is fundamentally necessary, where the processing of fuel is combined with the production of power, that a minimum number of heat units be lost to the steam-electric plant. Tar, oils, and ammonium sulphate contain relatively few heat units, and therefore in the recovery of these by-products a large portion of the original heat units remain available for making steam.

The results set forth above justify the conclusions given in the preceding section.

USE OF GAS FROM PROCESS-FUEL PLANTS IN INTERNAL-COMBUSTION ENGINES.

Gas engines have a higher thermal efficiency than prime movers that use steam, but they are so deficient in other characteristics that they can not at present be considered for superpower plants. The gas engine has not been developed in units of a size comparable with steam turbines, and investment and production costs for gas engines are much higher. These disadvantages outweigh the advantage gained by their higher thermal efficiency.

PULVERIZED COAL.

Pulverized coal has been successfully used in cement kilns and metallurgic furnaces for some time, but it is only in recent years that sufficient progress has been made in its adaptation to boiler furnaces to warrant its consideration. However, no large power plants have used this form of fuel long enough to give a reliable indication of the results.

As the future development of firing pulverized fuel may warrant its substitution for stokers, provision is made in the power station for sufficient combustion-chamber volume to allow the installation to be quickly and cheaply changed.

COST.

TABLE 99.—*Relative cost of process fuel and of coal for 300,000-kilowatt base-load steam-electric plants for the superpower system.*

	Coke from by-product coke ovens.	Gas from by-product coke ovens.	Semicarbocoal from low-temperature distillation plants.	Gas from bituminous gas producers.
Raw-fuel plant:				
Annual capacity factor ..... per cent..	70	70	70	70
Clearfield coal required per year for stoker operation, short tons	1,200,000	1,200,000	1,200,000	1,200,000
Process-fuel plant:				
Annual capacity factor ..... per cent..	80	70	80	70
Carbonization capacity:				
Daily ..... short tons..	6,850	42,000	6,850	7,570
Per year ..... do....	2,000,000	10,800,000	2,000,000	1,930,000
Resulting coke or semicarbocoal ..... do....	1,410,000	7,550,000	1,410,000	.....
Investment required:				
Total	$14,400,000	$88,000,000	$14,400,000	$22,710,000
Per cent of investment in power plant	45	280	45	71
Annual operating expense	$14,920,000	$80,600,000	$14,920,000	$14,400,000
Annual fixed charges	2,880,000	17,600,000	2,880,000	4,542,000
Total annual production expense	17,800,000	98,200,000	17,800,000	18,942,000
Credit from by-products except coke	6,240,000	16,600,000	8,440,000	6,180,000
	11,560,000	81,600,000	9,360,000	12,762,000
Return from coke sold	.....	75,550,000	.....	.....
Net annual cost of fuel	11,560,000	6,050,000	9,360,000	12,762,000
Cost of 1,200,000 tons of Clearfield coal for use raw	7,500,000	7,500,000	7,500,000	7,500,000
Difference:				
Total	4,060,000	−1,450,000	1,860,000	5,262,000
Per short ton of Clearfield coal	$3.38	−$1.21	$1.55	$4.38

APPENDIX L.

BASIC COSTS.

By the engineering staff.

CONSTRUCTION COSTS.

The costs for labor and materials in construction prevailing at midyear of 1919 are used unless otherwise specified.

FIXED CHARGES AGAINST INVESTMENT.

Fixed charges against investment have been subdivided into cost of money, depreciation and obsolescence, and taxes and insurance.

Cost of money.—Ten per cent has been taken as the cost of money for investments of all classes. The term "cost of money" is used to express the allowable return upon investment; it includes the rate of interest, discounts, and profit. The resulting final costs are the price at which energy can be sold by the superpower system with proper return upon its investment.

Depreciation and obsolescence.—The charge for depreciation and obsolescence is varied to provide reserves on an annuity basis for the several classes of investment against which it is figured. The percentages used are as follows:

	Per cent.
Steam-electric power plants	4
Hydroelectric power plants	3
Hydraulic works	1
Transmission lines	2
Substations	4

Taxes and insurance.—The following percentages have been used for taxes and insurance:

	Per cent.
Steam-electric power plants	2
Complete hydroelectric developments	1.5
Transmission lines	1.5
Substations	2

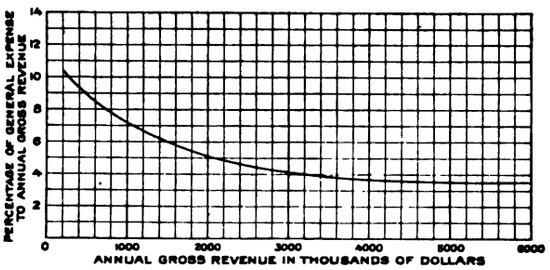


FIGURE 61.—Relation of general expense to annual gross revenue for 60 electric-utility companies in the superpower zone. Amortization fund, interest, taxes, and miscellaneous adjustments have been deducted.

GENERAL EXPENSE.

General expense includes provision for salaries and expenses of administrative officers, engineers, and legal counsel, salaries of clerks, claims, general stationery, printing, and store and stable expenses. Amortization, taxes, and insurance have been included under fixed charges rather than under general expense.

An examination of public-service commission records for 60 electric-utility companies in the superpower zone showed that general expense ranges from about 10.5 per cent for a gross annual revenue of $200,000 to about 3.5 per cent for a gross annual revenue of $5,000,000 or more, as is shown by figure 61.

OVERHEAD CHARGES AGAINST CONSTRUCTION.

The rate used for interest during construction is 7½ per cent, and this rate applied to the construction period for different classes of work results in the following charges: Steam-electric plants, 4½ per cent; hydroelectric plants, 6 per cent; transmission lines and substations, 3 per cent. Taxes during construction are figured at 1 per cent. Superintendence, engineering, and contingencies are figured at 15 per cent.

APPENDIX M.

STATIONS AND TRANSMISSION LINES OF ELECTRIC-POWER COMPANIES ENGAGED IN PUBLIC SERVICE.

By A. H. Horton.

The information given on Plate XI (in pocket) has been obtained from the power companies in the following manner: A proof map showing the stations and transmission lines of the public-utility companies in each State included in the superpower zone was prepared from the best information that could be obtained. A section of this map showing the stations and transmission lines operated by each company was sent to that company, which was requested to examine the map and report to the Geological Survey any errors detected or any changes that should be made. From the corrections and additions thus received a revised map of each State was prepared. The location of the power stations and transmission lines of those companies which did not reply to requests for information was determined from available published sources.

The maps were prepared to be published as separate State maps, and the accompanying map of the northeastern United States has been produced from these State maps by photolithography. The general outline of the superpower zone is shown on the map. In some of the congested areas in and around the large cities it was not possible to show all the power stations and transmission lines. However, the names and addresses of the companies that produce electricity for public use are shown in the following list, which includes the names of all companies in each State, even though only a portion of the State is shown on the map. The information on the map for New England and New York represents conditions in 1919; for Pennsylvania, New Jersey, Maryland, the District of Columbia, and Delaware, 1920; and for Virginia, 1921.

In this list the names of the operating companies are arranged in alphabetic order, and the corresponding file numbers assigned to them are in general arranged in numerical order. These file numbers are those used by the Geological Survey in its list of public utilities engaged in the production or distribution of electric energy. Where the numerical order conflicts with the alphabetic order the latter is followed, but the file number is repeated in the proper place, with the name of the operating company. Disarrangement of the numerical order is due to changes in the ownership of companies and to the inclusion in the list of certain manufacturing companies which sell for public use a part of the current they generate for manufacturing and which are distinguished by a different system of file numbers. The generating stations of a company that operates more than one station are indicated by letters (A, B, C, etc.) placed after the file numbers, as 5905–A; the substations of a company that operates more than one substation are indicated by prefixing figures (1, 2, 3, etc.) to the file numbers, as 1–5985. The file number assigned to a company added to the list after consecutive numbers had been assigned to companies preceding and following it consists of the preceding number with a figure added, as 5985–1. A file number that contains more than four digits indicates a company that is not engaged primarily in producing electric power or not operated as a public utility.

TABLE 100.—*Electric-power companies engaged in public service in the States in which the superpower zone is situated.*

Connecticut.

No.	Operating company.	Station.
900	Baltic Mills Co	Baltic.
901	Beacon Falls Electric Co	Beacon Falls.
902	Bristol & Plainville Tramway Co	Bristol.
903	Clinton Electric Light & Power Co	Clinton.
904	Central Connecticut Power & Light Co	Leesville.
24095	Cheney Bros	Manchester.
903	Clinton Electric Light & Power Co	Clinton.
906	Connecticut Co.:	
	A	Berlin.
	B	Bridgeport.
	C	Burrville.
	D	New Haven.
	F	West Haven.
	G	Hartford.
	H	Shelton.
	J	Danielson.
907	See Connecticut Power Co	Canaan, etc.
920	Connecticut Light & Power Co.:	
	A	Branford.
	B	Waterbury.
	C	Bulls Bridge.
	D	Stevenson.
907	Connecticut Power Co.:	
	A	Canaan.
	B	Falls Village.
	C	Middletown.
	D	New London.
909	Danbury & Bethel Gas & Electric Light Co	Danbury.
910	Danbury & Bethel Street Railway Co	Do.
911	Danielson & Plainfield Gas & Electric Co	Plainfield.
912	Derby Gas Co	Derby.
24136	Dunham Mills (Inc.)	Poquonock.
913	Eastern Connecticut Power Co.:	
	A	Montville.
	B	Tunnel.
	C	Hallville.
915	Essex Light & Power Co	Essex.
24150	Farmington River Power Co	Windsor.
917	Hartford Electric Light Co.:	
	A	Tariffville.
	B	Dutch Point.
918	Hartford & Springfield Street Railway Co	Warehouse Point.
24211	International Cotton Co	New Hartford.
920	*See* Connecticut Light & Power Co	Branford, etc.
921	Kent Electric Light & Gas Co	Kent.
922	Litchfield Electric Light & Power Co	Bantam.
924	Lyme Electric Power Co	Lyme.
951	Manchester Electric Co	South Manchester.
925	Meriden Electric Light Co	Meriden.
927	Municipal electric plant	Jewett City.
928	do	East Norwalk.
929	do	Norwich.
930	South Norwalk Electric Works	South Norwalk.
931	Municipal electric plant:	
	A	Wallingford.
	B	North Haven.
932	Mystic Power Co	Westerly.
934	New Hartford Electric Co	New Hartford.
936	New Milford Electric Light Co	New Milford.
938	New York, New Haven & Hartford Railroad Co	Coscob.
939	Northern Connecticut Light & Power Co	Windsor Locks.
942	Peoples Light & Power Co	Danielson.
945	Putnam Light & Power Co	Mechanicsville.
946	Ridgefield Electric Co	Ridgefield.
947	Rockville-Willimantic Lighting Co.:	
	A	Rockville.
	B	Stafford.
	C	Willimantic.
24376	Scovill Manufacturing Co	Waterbury.
949	Shore Line Electric Railway Co.:	
	A	Saybrook.
	B	Thamesville.
	D	Mystic.
	F	New London.

TABLE 100.—*Electric-power companies engaged in public service in the States in which the superpower zone is situated*—Con.

Connecticut—Continued.

No.	Operating company.	Station.
950	Simsbury Electric Co	Simsbury.
930	South Norwalk Electric Works	South Norwalk.
951	Manchester Electric Co	South Manchester.
952	Stamford Gas & Electric Co	Stamford.
953	Talcott Bros	Talcottville.
955	Torrington Electric Light Co	Torrington.
957	Uncas Power Co	Windham.
958	Union Electric Light & Power Co	Unionville.
960	United Illuminating Co.:	
	A	Bridgeport.
	B	New Haven.
963	Westport Water Co	Westport.
24773	Winchester Repeating Arms Co	New Haven.
965	Winsted Gas Co	Winsted.
966	Woodbury Electric Co	Woodbury.
24095	Cheney Bros	Manchester.
24136	Dunham Mills (Inc.)	Poquonock.
24150	Farmington River Power Co	Windsor.
24211	International Cotton Co	New Hartford.
24376	Scovill Manufacturing Co	Waterbury.
24473	Winchester Repeating Arms Co	New Haven.

District of Columbia.

1051	Capital Traction Co	Georgetown.
1051-1	East Washington Heights Traction Railroad Co	Washington.
1052	Potomac Electric Power Co.:	
	A	Bennings.
	B	Fourteenth Street.
1053	Washington Railway & Electric Co	Washington.
1054	Washington-Virginia Railway Co	Do.

Maine.

3300	Androscoggin Electric Co.:	
	A	Barkers Mills.
	B	Deer Rip No. 1.
	C	Lewiston No. 4.
	D	Littlefield No. 2.
3347	Androscoggin & Kennebec Railway Co	Hallowell.
3301	Aroostook Valley Railroad Co	Presque Isle.
3302	Atlantic Shore Railway Co.:	
	A	Estes.
	B	Kennebunkport.
	D	Old Falls.
3303	Bangor Power Co.:	
	A	Milford.
	B	Veazie.
3304	Bangor Railway & Electric Co	Bangor.
3305	Bar Harbor & Union River Power Co	Ellsworth.
3306	C. H. Bartlett Manufacturing Co	North New Portland.
3307	Belgrade Power Co	Belgrade.
3309	Berwick & Salmon Falls Electric Co	South Berwick.
3310	Bethel Light Co	Bethel.
3313	Bridgewater Electric Co	Bridgewater Center.
3314	Bridgton Water & Electric Co	Bridgton.
3315	Brownville Electric Light & Power Co	Brownville.
3318	Calais Street Railway Co.:	
	A	Calais.
	B	Do.
3319	Carrabassett Light & Power Co	North Anson.
3320	Caribou Water, Light & Power Co	Caribou.
3321	Central Maine Power Co.:	
	A	Augusta.
	B	Bath.
	C	Belfast.
	D	Brunswick.
	E	Benton.
	F	Fairfield.
	G	East Orland.

TABLE 100.—*Electric-power companies engaged in public service in the States in which the superpower zone is situated*—Con.

Maine—Continued.

No.	Operating company.	Station.
3321	Central Maine Power Co.—Continued.	
	H	Fairfield.
	J	Farmingdale.
	K	East Dover.
	L	Greenville.
	M	Burnham.
	N	Union Gas.
	P	Skowhegan.
	R	Do.
	T	Waterville.
	V	Oakland.
	W	Winslow.
	X	Rice Rips.
	Y	Skowhegan.
	AA	Brunswick.
3322	Cherryfield Electric Light Co	Cherryfield.
3323	Clark Power Co	Union Falls.
3324	Cornish & Kezar Falls Light & Power Co	Kezar Falls.
3325	Cumberland County Power & Light Co.:	
	A	Bonny Eagle.
	B	North Gorham.
	C	Bar Mills.
	D	West Buxton.
	E	Hiram.
	F	Forest Avenue.
	G	Plum Street.
3326	Danforth Electric Light Co	Danforth Village.
3327	Dennistown Power Co	Jackman.
3329	Easton Electric Co	Easton.
3330	Eastport Electric Light Co	Eastport.
3333	Farmington Power Co	Farmington.
3334	Fort Fairfield Light & Power Co	Fort Fairfield.
3336	Fort Kent Electric Co	Wallagrass.
3337	Franklin Light & Power Co	Anson.
3338	Fryeburg Electric Light Co	Fryeburg.
3339	Gould Electric Co	Presque Isle.
3340	Hartland Electric Light Co	Hartland.
3341	Houlton Water Co	Houlton.
35743	International Paper Co	Livermore Falls.
3343	Island Lighting Co	Island Falls.
3344	Vinalhaven Light & Power Co	Vinalhaven.
3346	Kingfield Light Co	Kingfield.
3347	Androscoggin & Kennebec Railway Co	Hallowell.
3348	Western Maine Power Co	Limerick.
3349	Limestone Light & Power Co	Limestone.
3376	Lincoln County Power Co.:	
	A	Damariscotta Mills.
	B	Bristol.
3350	Lisbon Falls Electric Co	Boston, Mass.
3351	Livermore Falls Light & Power Co	Livermore Falls.
3352	Washington County Light & Power Co	Machias, etc.
3354	Merrill Mill Co	Patten.
3355	Mallison Power Co	South Windham.
3354	Merrill Mill Co	Patten.
3356	Milo Electric Light & Power Co.:	
	A	Milo.
	B	Sebec.
3357	Monmouth Electric Co	Monmouth.
3358	Monson Light & Power Co	Monson.
3359	Monticello Electric Co	Monticello.
3360	G. H. Mooers	Ashland.
3361	Municipal electric plant	Bangor.
3363	do	Kennebunk.
3364	do	Lewiston.
3365	do	Madison.
3366	do	Newport.
3367	Oquossoc Light & Power Co	Kennebago Falls.
3368	Oxford Electric Co.:	
	A	Mechanic Falls.
	B	Norway.
	C	South Paris.
3370	Pennamaquam Power Co	Pembroke.

TABLE 100.—*Electric-power companies engaged in public service in the States in which the superpower zone is situated*—Con.

Maine—Continued.

No.	Operating company.	Station.
3373	Phillips Electric Light & Power Co	Phillips.
3376	Lincoln County Power Co	Damariscotta Mills, etc.
3377-1	Portsmouth, Dover & York Street Railway Co	Kittery Point.
3378	Presumpscot Electric Co.:	
	A	Dundee.
	B	Eel Weir.
	C	Saccarappa.
	D	Smelt Hill.
3379	Readfield Light & Power Co	Readfield.
3382	Rumford Falls Light & Water Co	Rumford.
3383	Rumford Falls Power Co	Do.
3385	Somerset Traction Co	Skowhegan.
3388	Stratton Electric Light Co	Eustis.
3389	Swan Falls Co	Fryeburg.
3390	C. A. Thompson & Co	New Sharon.
3391	Turner Light & Power Co	Turner.
3391-1	Turner Transformer Co	South Turner.
3392	Van Buren Light & Power district	Van Buren.
3344	Vinalhaven Light & Power Co	Vinalhaven.
3352	Washington County Light & Power Co.:	
	A	Machias.
	B	Pleasant River.
3348	Western Maine Power Co	Limerick.
3395	Westfield Electric Co	Westfield.
3396	A. George Weymouth	Farmington Falls.
3397	Wilton Light Co	Wilton.
35799	Wing Spool & Bobbin Co	Kingfield.
3400	Winthrop & Wayne Light & Power Co	Winthrop.
3401	Wiscasset Electric Light & Power Co	Wiscasset.
3403	Yarmouth Lighting Co	Yarmouth.
3404	York County Power Co.:	
	A	Biddeford.
	B	Sanford.
35743	International Paper Co	Livermore Falls.
35799	Wing Spool & Bobbin Co	Kingfield.

Maryland.

3500	Annapolis Public Utilities Co	Annapolis.
3501	Antietam Electric Light & Power Co	Breathedsville.
3502	Baltimore County Electric Co	Baltimore.
3504	Baltimore, Halethorpe & Elkridge Railway Co	Do.
3505	Baltimore, Sparrows Point & Chesapeake Railway Co	Do.
3506	Baltimore & Bel Air Electric Railway Co	Bel Air.
3508	Bel Air Electric Co.:	
	A	Bel Air No. 1.
	B	Bel Air No. 2.
3509	E. A. C. Bucky	Union Bridge.
3510-1	Capital Traction Co	Chevy Chase.
3511	Chestertown Electric Light & Power Co	Chestertown.
3513	Consolidated Gas, Electric Light & Power Co.:	
	A	Ilchester.
	C	Westport.
3514	Consolidated Public Utilities Co	Westminster.
3513	Consumers Ice Co	Crisfield.
3516	Cumberland Electric Railway Co	Cumberland.
3517	Cumberland & Westernport Electric Railway Co.:	
	A	Clarysville.
	B	Reynolds.
3518	Delmarvia Utilities Co	Ocean City.
3519	Eastern Shore Gas & Electric Co.:	
	A	Denton (hydroelectric).
	B	Salisbury.
	C	Denton (steam).
3520	Edison Electric Illuminating Co	Cumberland.
3521	Electric Ice Manufacturing Co	Pocomoke City.
3522	Elkton Electric Light & Power Co	Elkton.
3523	Emmitsburg Electric Co	Emmitsburg.
3524	Gilpins Falls Electric Co	Gilpins Falls.
3525	Hagerstown & Frederick Railway Co	Security.

TABLE 100.—*Electric-power companies engaged in public service in the States in which the superpower zone is situated*—Con.

Maryland—Continued.

No.	Operating company.	Station.
3526	Havre de Grace Electric Co.	Havre de Grace.
3526-1	Hillsboro Lighting Co.	Hillsboro.
3527	Home Electric Light Co.	Lonaconing.
3528	Home Manufacturing Light & Power Co.	Elkton.
3530	Kensington Railway Co. & Sandy Spring Railway Co.	Kensington.
3531	Lorraine Electric Railway	Baltimore.
3532	Maryland Electric Railways Co.	Annapolis.
3533	Midland Electric Light Co.	Midland.
3534	Mountain Lake Park Association	Mountain Lake Park.
3535	Mount Washington Electric Light & Power Co.	Baltimore.
3536	Municipal electric plant	Aberdeen.
3537	do	Berlin.
3538	do	Centerville.
3540	do	Easton.
3541	do	Frederick.
3542	do	Hagerstown.
3543	do	Laurel.
3543-1	do	Queenstown.
3543-2	do	Rock Hall.
3544	do	Williamsport.
3545	New Windsor Electric Light & Water Co.	New Windsor.
3545-1	Northern Maryland Electric Co.	Oxford, Pa.
3546	Oakland Electric Co.	Oakland.
3549	Perryville Electric Co.	Perryville.
3550	Port Deposit Electric Co.	Port Deposit.
3551	Princess Anne Electric Plant	Princess Anne.
3552	St. Michaels Utilities Commission	St. Michaels.
3555	Snow Hill Electric Light & Power Co.	Snow Hill.
3551-1	Stockton Electric Light Co.	Stockton.
3557	Towson & Cockeysville Electric Railway Co.	Bel Air.
3558	Union Bridge Electric Manufacturing Co.	Union Bridge.
3559	United Railways & Electric Co.:	
	C	Owings Mills, Baltimore.
	D	Pratt Street, Baltimore.
3560	Washington, Baltimore & Annapolis Electric Railroad Co.	Baltimore.

Massachusetts.

3601	Agawam Electric Co.	Springfield.
3602	American Woolen Co.	Maynard.
3603	Amesbury Electric Light Co.	Amesbury.
3604	Amherst Gas Co.	Amherst.
3605	Athol Gas & Electric Co.:	
	A	Athol.
	B	Wendell Depot.
	C	Farley.
3607	Attleboro Steam & Electric Co.	Attleboro.
3608	Ayer Electric Light Co.	Ayer.
3609	Eastern Massachusetts Street Railway Co.	Byfield, etc.
3610	Berkshire Street Railway Co.:	
	A	Pittsfield.
	B	Zylonite.
3611	Beverly Gas & Electric Co.	Beverly.
3612	Blackstone Electric Light Co.	Blackstone.
3614	Blue Hill Street Railroad Co.	Canton.
3616	Boston Elevated Railway Co.:	
	A	Central.
	B	Charlestown.
	C	Dorchester.
	D	Cambridge.
	E	Lincoln.
	F	South Boston.
3618	Boston & Worcester Street Railroad Co.	Framingham.
3620	Brockton & Plymouth Street Railway Co.	Plymouth.
3621	Buzzards Bay Electric Co.	Falmouth.
3622	Cambridge Electric Light Co.	Cambridge.
37440-1	Cape Cod Cold Storage Co.	Provincetown.
3623	Central Massachusetts Electric Co.	Blanchardville.
3626	Charlemont Electric Light & Power Co.	Charlemont.
3627	Charlestown Gas & Electric Co.	Charlestown.

TABLE 100.—*Electric-power companies engaged in public service in the States in which the superpower zone is situated*—Con.

Massachusetts—Continued.

No.	Operating company.	Station.
3628	Chester Electric Light Co	Chester.
3629	Citizens Gas, Electric Light & Power Co	Nantucket.
3630	Clinton Gas Light Co	Clinton.
3631	Concord, Maynard & Hudson Street Railroad Co	Maynard.
3633	Conway Electric Street Railway Co	Conway.
3633-1	Eastern Massachusetts Electric Co	Boston.
3609	Eastern Massachusetts Street Railway Co.:	
	A	Byfield.
	B	Chelsea.
	C	Essex Falls.
	D	Gloucester.
	E	Haverhill.
	F	Hyde Park.
	H	Lawrence.
	J	Quincy.
	K	Lynn.
	L	Salem.
	M	Woburn.
	N	Lowell.
3634	Easthampton Gas Co	Montague City.
3636	Edison Electric Illuminating Co. of Boston:	
	A	South Boston.
	D	Atlantic Avenue.
3637	Edison Electric Illuminating Co. of Brockton	East Bridgewater.
3638	Electric Light & Power Co. of Abington and Rockland	North Abington.
3639	Fall River Electric Light Co	Fall River.
3640	Fitchburg Gas & Electric Light Co	Fitchburg.
3641	Fitchburg & Leominster Street Railway Co.:	
	A	Do.
	B	Do.
3642	Franklin Electric Light Co	Turners Falls.
3643	Gardner Electric Light Co	Gardner.
3644	Gloucester Electric Co	Gloucester.
3646	Greenfield Electric Light & Power Co.:	
	A	Greenfield.
	B	Gardner Falls.
3648	Haverhill Electric Co	Haverhill.
3649	Holyoke Street Railway Co	Holyoke.
3950	Holyoke Water Power Co	Do.
3651	Huntington Electric Light Co	Huntington.
3653	Interstate Consolidated Street Railway Co	Springfield.
3655	Lawrence Gas Co	Lawrence.
3656	Lee Electric Co	Lee.
3658	Leominster Electric Light & Power Co	Leominster.
3660	Lowell Electric Light Corporation	Lowell.
3662	Ludlow Electric Light Co	Ludlow.
3664	Lynn Gas & Electric Co	Lynn.
3665	Malden Electric Co	Malden.
3666	Manchester Electric Co	Manchester.
3667	Marlboro Electric Co	Marlboro.
3669	Merrimac Valley Building & Power Co	Amesbury.
3669-1	Metropolitan District Commission:	
	A	Wachusett.
	B	Sudbury.
3671	Middletown Electric Light Co	Middletown.
3672	Milford, Attleboro & Woonsocket Street Railway Co	Unionville.
3673	Milford Electric Light & Power Co	Boston.
3675	Mill River Electric Co	Williamsburg.
3676	Monument Mills:	
	A	Stockbridge No. 1.
	B	Stockbridge No. 2.
3677	Municipal electric plant	Ashburnham.
3678	.....do	Belmont.
3679	.....do	Boylston Center.
3681	.....do	Chicopee.
3682	.....do	Concord.
3683	.....do	Danvers.
3684	.....do	East Braintree.
3684-1	.....do	Georgetown.
3685	Pepperell Electric Light & Power Co	East Pepperell.
3686	Municipal electric plant	Groton.
3687	.....do	Groveland.

TABLE 100.—*Electric-power companies engaged in public service in the States in which the superpower zone is situated*—Con.

Massachusetts—Continued.

No.	Operating company.	Station.
3688	Municipal electric plant	Hingham.
3689	.....do	Holden.
3690	.....do	Holyoke.
3691	.....do	Hudson.
3692	.....do	Hull.
3693	.....do	Ipswich.
3694	.....do	Littleton.
3695	.....do	Lunenburg.
3696	.....do	Mansfield.
3697	.....do	Marblehead.
3698	.....do	Merrimac.
3699	.....do	Middleboro.
3700	.....do	North Attleboro.
3725	.....do	North Dana.
3701	.....do	Norwood.
3702	.....do	Peabody.
3704	.....do	Reading.
3705	.....do	Rowley.
3706	.....do	Shrewsbury.
3707	.....do	South Hadley.
3708	.....do	Sterling.
3709	.....do	Taunton.
3710	.....do	Templeton.
3711	.....do	Wakefield.
3712	.....do	Wellesley.
3713	.....do	West Boylston.
3714	.....do	Westfield.
3717	New Bedford Gas & Edison Light Co	New Bedford.
3719	Newburyport Gas & Electric Co	Newburyport.
3720	New England Power Co.:	
	A	Deerfield No. 5.
	B	Deerfield No. 2.
	C	Deerfield No. 3.
	D	Deerfield No. 4.
	E	Fitchburg.
	F	Uxbridge.
3721	Norfolk & Bristol Street Railway Co	South Walpole.
3722	North Adams Gas Light Co	North Adams.
3723	Northampton Electric Lighting Co	Northampton.
3724	Northampton Street Railway Co	Do.
3725	Municipal electric plant	North Dana.
3727	Norton Power & Electric Co	Chartley.
3729	Norton, Taunton & Attleboro Street Railway Co	Norton.
3685	Pepperell Electric Light & Power Co	East Pepperell.
3734	Pittsfield Electric Co.:	
	A	Silver Lake.
	B	Pittsfield.
3735	Plymouth Electric Light Co	Plymouth.
3739	Provincetown Light & Power Co	Provincetown.
3740	Quincy Electric Light & Power Co	Quincy.
3741	Randolph & Holbrook Power & Electric Co	Randolph.
3742	Salem Electric Lighting Co	Salem.
3743	Seekonk Electric Co	Seekonk.
3744	Shelburne Falls & Colerain Street Railway Co	Shelburne Falls.
3745	Shirley Electric Co	Shirley.
3746	Southeastern Massachusetts Power & Electric Co	Marion.
3747	Spencer Gas Co	Spencer.
3749	Southern Berkshire Power & Electric Co	Great Barrington.
3751	Suburban Gas & Electric Co	Revere.
3752	Sunderland Electric Light & Power Co	Sunderland.
3755	Turners Falls Power & Electric Co.:	
	A	Hampden.
	B	Turners Falls.
	C	Cabot.
3756	Tyngsboro Electric Light Co	Tyngsboro.
3757	Union Light & Power Co	Franklin.
3758	Union Street Railway Co	New Bedford.
3759	United Electric Light Co.:	
	A	Indian Orchard.
	B	Bircham Bend.
	C	Springfield.

TABLE 100.—*Electric-power companies engaged in public service in the States in which the superpower zone is situated*—Con.

Massachusetts—Continued.

No.	Operating company.	Station.
3760	Vineyard Lighting Co.:	
	A	Vineyard Haven.
	B	Oak Bluffs.
3761	Ware Electric Co	Ware.
3764	Webster & Southbridge Gas & Electric Co	Webster.
3764-1	Westfield Power Co	Westfield.
3765	Weymouth Light & Power Co	East Weymouth.
3766	Williamstown Gas Co	Williamstown.
3767	Winchendon Electric Light & Power Co	Winchendon.
3768	Worcester Consolidated Street Railway Co.:	
	B	Leominster.
	C	Milbury.
	D	Northboro.
	E	West Berlin.
3769	Worcester Electric Light Co	Webster Street.
3770	Worcester Suburban Electric Co	Uxbridge.
37440-1	Cape Cod Cold Storage Co	Provincetown.

New Hampshire.

5400	William F. Allen Light Co	West Stewartstown.
5401	Alton Electric Light & Power Co	Alton.
5402	Antrim-Bennington Electric Light & Power Co.:	
	A	Antrim.
	B	Bennington.
5403	Municipal Electric Commission	Ashland.
5404	Berlin Street Railway Co	Gorham.
5405	Bethlehem Electric Co	Bethlehem.
5406	*See* Concord Electric Railways	Franklin, etc.
5407	Bradford Light & Power Co	Bradford.
5408	Bristol Electric Light Co	Bristol.
5410	Canaan & Enfield Electric Co	Raymond.
5412	Vermont Hydro Electric Corporat'on	Claremont.
5414	Cloutman Gas & Electric Co	Farmington.
5415	Concord Electric Co	Sewalls Falls.
5406	Concord Electric Railways:	
	A	Franklin.
	B	West Concord.
5416	Contoocook Electric Light Co	Davisville.
5417	Conway Electric Light & Power Co	Center Conway.
5418	Derry Electric Co	Derry.
5422	Exeter & Hampton Electric Co	Exeter.
5423	O. D. Fessenden	South Brookline.
5424	Franklin Light & Power Co.:	
	A	Franklin.
	B	Salmon Brook.
5425	Goodrich Falls Electric Co	Goodrich Falls.
5425-1	Grafton County Electric Light & Power Co.:	
	A	West Lebanon.
	B	Lebanon.
	C	West Lebanon.
5426	Greenville Electric Lighting Co	Greenville.
5427	Groveton Electric Light Co	Groveton.
5429	Hillsboro Electric Light & Power Co	Hillsboro.
5430	Hollis Electric Light Co	Hollis.
5431	Jones & Linscott Electric Co	Lancaster.
5432	Keene Gas & Electric Co.:	
	A	Swanzey.
	B	Do.
	C	Dublin.
	D	Peterboro.
	E	Marlboro.
5433	Laconia Gas & Electric Co.:	
	A	Lochmere.
	B	Lakeport.
5435	Lisbon Light & Power Co.:	
	A	Lisbon.
	B	Bath.
	C	Lisbon.

TABLE 100.—*Electric-power companies engaged in public service in the States in which the superpower zone is situated*—Con.

New Hampshire—Continued.

No.	Operating company.	Station.
5437	Manchester Traction, Light & Power Co.:	
	A	Brook Street.
	C	Garvin Falls.
	D	Greggs Falls.
	E	Hooksett.
	F	Kelleys Falls.
	G	Nashua.
5442	Meredith Electric Light Co	Meredith.
5443	Milford Light & Power Co	Milford.
5403	Municipal Electric Commission	Ashland.
5444	Municipal electric plant	Littleton.
5445	do	Wolfeboro.
5447	New Hampshire Water & Electric Power Co	Fitzwilliam.
5448	New Hampton Electric Light & Power Co	New Hampton.
5450	Newport Electric Light Co.:	
	A	Newport.
	B	North Newport.
46459-1	Parker Young Co.:	
	A	Lincoln.
	B	Do.
5454	Pittsfield Light & Power Co	Pittsfield.
5455	Plymouth Electric Light Co	Plymouth.
5457	Raymond Electric Co	Raymond.
5458	Rockingham County Light & Power Co.:	
	A	Portsmouth.
	B	Durham.
5458-1	Rumney Electric Co	Rumney.
5459	Salem Electric Light Co	North Salem.
5462	Sunapee Electric Light & Power Co	Sunapee.
5463	Tilton Electric Light & Power Co	Tilton.
5465	Twin State Gas & Electric Co.:	
	A	Dover.
	B	Gorham.
	C	Milton.
5412	Vermont Hydro Electric Corporation	Claremont.
5468	Wentworth-Hall Electric Co	Jackson.
5469	West Campton Electric Light Co	West Campton.
5470	Whitefield Electric Light Co	Whitefield.
5471	Wonalancet Electric Co	Wonalancet.
5472	Woodsville Aqueduct Corporation	Woodsville.
46459-1	Parker Young Co	Lincoln.

New Jersey.

5500	Atlantic City Electric Co.:	
	A	Atlantic City.
	B	Ocean City.
	C	Pleasantville.
5502	Atlantic City & Shore Railroad Co	Atlantic City.
5503	Atlantic Coast Electric Light Co	Asbury Park.
5504	Atlantic Coast Electric Railway Co	Allenhurst.
5505	Atlantic County Electric Co	Egg Harbor.
5506	Atlantic & Suburban Railway Co	Pleasantville.
5506-1	Barnegat Light & Power Co	Seaside Heights.
5507	Blair Electric Light Co	Blairstown.
5508	Boonton Electric Co	Boonton.
5509	Branchville Electric Power, Water & Lighting Co	Branchville.
5511	Bridgeton & Millville Traction Co	Bridgeton.
5513	Burlington County Transit Co	Hainesport.
5514	Califon Electric Light & Power Co	Califon.
5593	Cape May Court House Light & Water Co	Cape May Court House
5515	Cape May Light & Power Co	Cape May.
5517	Central Passenger Railway Co	Atlantic City.
5594	E. R. Collins & Son:	
	A	Market Street, Belvidere.
	B	South Water Street, Belvidere.
5519	Commonwealth Electric Co	Summit.
5520	Consolidated Gas Co. of New Jersey	Long Branch.
5522	Pennsylvania Utilities Co	Columbia.

TABLE 100.—*Electric-power companies engaged in public service in the States in which the superpower zone is situated*—Con.

New Jersey—Continued.

No.	Operating company.	Station.
5523	Electric Co. of New Jersey:	
	A	Salem.
	B	Bridgeton.
5524	Electric Light & Power Co	Hightstown.
5524-1	Eureka Power Co	Trenton.
5525	Five Mile Beach Electric Railway Co	Camden.
5526	Flemington Electric Light, Heat & Power Co	Flemington.
5527	Hackettstown Electric Light Co	Hackettstown.
5528	Hammonton & Egg Harbor City Gas Co	Hammonton.
5529	Harrison Heights Improvement Co	Mullica Hill.
5530	Hoboken Shore Road	Hoboken.
5531	Hunterdon Electric & Power Co	High Bridge.
5533	Jamesburg Electric Co	Jamesburg.
5534	Jersey Central Traction Co	Keyport.
5536	Jersey Electric Co	High Bridge.
5536-1	J. C. Kennedy Electric Co	Long Valley.
5537	Lakewood & Coast Electric Co	Lakewood.
5538	Lambertville Public Service Co	Lambertville.
5540	Millburn Electric Co	Millburn.
5541	Millville Electric Light Co.:	
	A	Sharp Street.
	B	Second Street.
47543	Millville Manufacturing Co	Millville.
5542	Millville Traction Co	Do.
5543	Monmouth County Electric Co	Red Bank.
5544	Monmouth Lighting Co	Keyport.
5546	Morris County Traction Co	Morristown.
5547	Morris Railroad Co	Do.
5548	Morris & Somerset Electric Co	Do.
5549	Municipal electric plant	Allentown.
5550	do	Andover.
5551	do	Atlantic Highlands.
5525	do	Butler.
5553	do	Chatham.
5554	do	Frenchtown.
5555	do	Madison.
5556	do	Orange.
5557	do	Park Ridge.
5557-1	do	Pompton Lakes.
5558	do	Seaside Park.
5559	do	South River.
5560	do	Vineland.
5561	New Egypt Light, Heat, Power & Water Co	New Egypt.
5562	New Jersey Power & Light Co.:	
	C	Dover.
	D	Boonton.
5564	New Jersey & Pennsylvania Traction Co	Trenton.
5565	New Jersey Water & Light Co	Deal Beach.
5565-1	New York Edison Co	Jersey City power house.
5566	Newton Gas & Electric Co	Newton.
5566-1	Northampton, Easton & Washington Traction Co	Port Colden.
5567	North Jersey Rapid Transit Co	Paterson.
5568	Ocean City Electric Railroad Co	Ocean City.
5569	Ocean Grove Camp Meeting	Bradley Beach.
5522	Pennsylvania Utilities Co	Columbia.
5571	Phillipsburg Transit Co	Phillipsburg.
5575	Public Service Electric Co.:	
	A	Edgewater.
	B	Metuchen.
	D	Buckingham Avenue.
	E	Red Bank.
	F	City dock, Newark.
	G	Coal Street, Newark.
	H	Hoboken.
	I	Marion (Jersey City).
	J	Paterson.
	K	Camden.
	L	Burlington.
	N	Plainsboro.
	O	Trenton.
	P	Cranford.
	R	Secaucus.
	S	Essex.

TABLE 100.—*Electric-power companies engaged in public service in the States in which the superpower zone is situated*—Con.

New Jersey—Continued.

No.	Operating company.	Station.
5576	Public Service Railway Co	Newark.
5577	Rockland Electric Co. of New Jersey	Gloucester.
47551	Sayre & Fisher Co	Sayreville.
5580	Sayreville Electric Light & Power Co	Do.
5581	Seacoast Traction Co	Seagirt.
5582	Sea Isle City Electric Light, Power & Water Co	Sea Isle City.
5584	Stone Harbor Electric Light & Power Co	Stone Harbor.
5587	Toms River Electric Co	Toms River.
5588	Trenton, Lakewood & Seacoast Railway	Trenton.
5589	Trenton, Lawrenceville & Princeton Railroad Co	Do.
5590	Trenton & Mercer Co. Traction Corporation	Do.
5591	Trenton Street Railway Co	Do.
5598	Vulcan Power Co	Netcong.
5593	Cape May Court House Light & Water Co	Cape May Court House.
5594	E. R. Collins & Son:	
	A	Market Street, Belvidere.
	B	South Water Street, Belvidere.
5595	Washington Electric Co	Washington.
5596	West Jersey Electric Co	Wildwood.
5597	West Jersey & Seashore Railroad Co	Westville.
5598	Vulcan Power Co	Netcong.
5600	Woodbine Land & Improvement Co	Woodbine.
5601	Woodbourne Electric Light, Heat & Power Co	Woodbourne.
47543	Millville Manufacturing Co	Millville.
47551	Sayre & Fisher Co	Sayreville.

New York.

5800	Adams Electric Light Co	Adams.
5801	Addison Electric Light & Power Co	Addison.
6180	Adirondack Power & Light Corporation:	
	A	Johnsonville.
	B	Schaghticoke.
	C	East Creek.
	D	Inghams Mills.
	E	Mechanicsville.
	F	Schoharie Falls.
	G	Spier Falls.
	H	Utica.
	J	Kanes Falls.
	K	North Granville.
	L	Granville.
5804	Adrian Knitting Co	Sanquoit.
5805	Afton-Windsor Light, Heat & Power Co. (Inc.)	Center Village.
5806	Albany Southern Railroad Co	Stuyvesant Falls.
5807	Antwerp Light & Power Co	Antwerp.
5809	Atlantic Light & Power Co	Coeymans.
5811	Auburn & Syracuse Electric Railroad	Syracuse.
5812	Aurora Electric Light Co	Aurora.
5813	Ausable Valley Light, Heat & Power Co	Keene.
5814	Avon Electric Co	Avon.
5817	Batavia Traction Co	Batavia.
5946	Berkshire Street Railway Co	Walloomsac.
5821	Berlin Electric Light, Heat & Power Co	Berlin.
5822	Binghamton Light, Heat & Power Co.:	
	A	Binghamton.
	B	Johnson City.
5823	Binghamton Railway Co	Binghamton.
5824	Black River Traction Co	Watertown.
5825-1	Bombay Electric Corporation	Bombay.
5826	Boquet Electric Power Co	Essex.
5827	Broadalbin Electric Light & Power Co	Broadalbin.
5828	Bronx Gas & Electric Co	Bronx.
5893	Brooklyn Edison Co	Gold Street.
5832	Brooklyn Rapid Transit Co.:	
	A	Central Power.
	B	Williamsburg.
	C	Ninth Street.
5833	Bryant Power Co. (Inc.)	Buffalo.
5834	Buffalo General Electric Co	Do.

TABLE 100.—*Electric-power companies engaged in public service in the States in which the superpower zone is situated*—Con.

New York—Continued.

No.	Operating company.	Station.
5835	Rochester, Lockport & Buffalo Railroad Corporation	Rochester.
5836	Buffalo & Depew Railway Co	Buffalo.
5839	Buffalo & Williamsville Electric Railway Co	Williamsville.
5840	Buffalo Southern Railway Co	Ebenezer.
5842	Callicoon Independent Electric Co. (Inc.)	Callicoon.
5843	Canaseraga Heat, Light & Power Co	Canaseraga.
5843-1	Canisteo Light & Power Co	Canisteo.
5844	Canton Electric Light & Power Co	Canton.
5846	Cattaraugus Electric Light & Power Co	Cattaraugus.
5847	Cayadutta Generating Co	Berryville.
5847-1	Cayuga Power Corporation	Portland Point.
5848	Cazenovia Electric Co	Cazenovia.
5849	Central Hudson Gas & Electric Co.:	
	A	Newburgh.
	B	Poughkeepsie.
5851	Central New York Power Co	Canastota.
5853	Champlain Electric Co	Champlain.
5854	Chasm Power Co	Chateaugay.
5855	Chautauqua Traction Co	Jamestown.
5856	Chatham Electric Light, Heat & Power Co	Chatham.
48834	A. C. Cheney Piano Action Co	Castleton.
5858	Clinton Hematite Mines	Clinton.
5858-1	Clymer Power Corporation	Clymer.
5859	Cohoes Power & Light Corporation	Cohoes.
5862	Cold Spring Light, Heat & Power Co	Cold Spring.
5863	College Hill Electric Light Co	Clinton.
5867	Consolidated Electric Co	Middle Falls.
5868	Consolidated Light & Power Co	Whitehall.
5868-1	Consumers Gas Co	Southampton.
5869	Corinth Electric Light & Power Co	Corinth.
5869-1	Corning Light & Power Corporation	Corning.
5871	Cortland County Traction Co	Cortland.
5873	Croton Falls Electric Light Plant	Croton Falls.
5874	Dansville Gas & Electric Co	Dansville.
5875	Deansboro Electric Light Plant	Deansboro.
5876	Deer River Power Co	Copenhagen.
5877	Delaware County Electric Light & Power Co	Delhi.
5878	Delaware & Otsego Light & Power Co	Franklin.
5879	Depew & Lancaster Light, Power & Conduit Co	Lancaster.
5882	Dundee Electric Lighting Plant	Dundee.
50256-1	John Dunlop's Sons	Phoenix.
5885	Dutchess Light, Heat & Power Co	Rhinebeck.
5886	Dwaas Electric Co	Hudson Falls.
5887	Earlville Electric Light Co	Earlville.
5888	East Aurora Electric Light Co	East Aurora.
5891	East Hampton Electric Light Co	East Hampton
5892	Eaton-Morrisville Power Co.:	
	A	Eaton.
	B	Morrisville.
5893	Brooklyn Edison Co	Gold Street.
5895	Edwards Light & Power Co	Edwards.
5896	Electric Light Co. of Newpaltz	Newpaltz.
5897	Elizabethtown Electric Plant	Elizabethtown.
5898	Ellenville Electric Co	Ellenville.
5900	Elmira, Corning & Waverly Railroad	Elmira.
5901	Elmira Water, Light & Railroad Co	Do.
5903	Empire Gas & Electric Co.:	
	A	Auburn.
	B	Geneva.
	C	Lyons.
	D	Newark.
	E	Waterloo.
	F	Seneca Falls.
5904	Empire State Railroad Corporation	Oswego.
5905	Erie Railroad Co	Rochester.
5906	Falconer Electric Light Co	Falconer.
49143	Endicott, Johnson & Co	Johnson City.
5907	W. H. Faxon Electric Plant	Chestertown.
5908	Fishers Island Electric Light & Power Co	Fishers Island.
5909	Fishkill Electric Railway Co	Bacon.
5910	Flatbush Gas Co	Brooklyn.
5911	Fonda, Johnstown & Gloversville Railroad	Tribes Hill.

TABLE 100.—*Electric-power companies engaged in public service in the States in which the superpower zone is situated*—Con.

New York—Continued.

No.	Operating company.	Station.
5912	Forestport Electric Light Plant	Forestport.
5913	Fort Covington Light, Heat & Power Co	Fort Covington.
5914	Fort Plain Gas & Electric Light, Heat & Power Co	Fort Plain.
5916	Franklin Springs & Progressive Electric Light Co	Franklin Springs.
5917	Fulton Chain Electric Co	Fulton Chain.
5918	Fulton County Gas & Electric Co.:	
	A	Gloversville.
	B	Samonsville.
5919	Fulton Light Heat & Power Co	Fulton.
5920	Garden City Co	Garden City.
5921	Garner Print Works & Bleachery	Wappingers Falls.
49275	General Electric Co	Schenectady.
5922	Genesee Light & Power Co	Batavia.
5923	Genesee Valley Power Co	Mills Mills.
5924	Geneseo Gas Light Co	Geneseo.
5925	Geneva, Seneca Falls & Auburn Railroad Co. (Inc.)	Seneca Falls.
5926	G. N. Gibson & Sons	West Stockholm.
5927	Glen Cove Light & Power Co	Glen Cove.
5929	Glens Falls Gas & Electric Light Co	Glens Falls.
5930	Goshen Light & Power Co	Monroe.
49320	Gould Paper Co	Lyons Falls.
5932	Granville Electric & Gas Co	Granville.
5933	Great Bear Light & Power Co	East Worcester.
5934	Gregory Electric Co. (Inc.)	Morristown.
6041	Groton Electric Power Corporation	Groton.
5935	Halfmoon Light, Heat & Power Co	Mechanicsville.
5936	E. S. Hamblin & Co	Oriskany Falls.
5937	Hammondsport Electric Light Co	Hammondsport.
5938	Hanford Bros	East Meredith.
5939	Hannawa Falls Water Power Co	Hannawa Falls.
5940	Harlem Valley Light, Heat & Power Co	Pawling.
5942	Hermon Electric Co	Hermon.
5943	Hilton Electric Light, Power & Heat Co	Hilton.
5944	Holmes Milling Co	Downsville.
5945	Honk Falls Power Co.:	
	A	Napanoch.
	B	High Falls.
5946	Berkshire Street Railway Co	Walloomsac.
5947	Hornell Electric Co	Hornell.
5950	Hudson Valley Railway Co.:	
	A	Middle Falls.
	B	Stillwater.
	C	Mechanicsville.
5951	Hudson & Manhattan Railroad Co	Terminal Building.
6164	Alfred Huntington	Ripley.
5954	Hydro Electric Power Co	Theresa.
5955	Interborough Rapid Transit Co.:	
	A	East River.
	B	North River.
5957	International Railway Co	Niagara Street, Buffalo.
5960	New York State Gas & Electric Corporation	Oneonta.
6159	Iroquois Utilities (Inc.)	Randolph.
5961	Ithaca Traction Co	Ithaca.
5962	Jamestown Lighting & Power Co	Jamestown.
5963	Jamestown Street Railway Co	Do.
5964	Jamestown, Westfield & North-Western Railroad Co	Do.
5965	Jordan Electric Light & Power Co	Jordan.
5968	Katonah Lighting Co	Bedford Hills.
5970	Kingston Consolidated Railroad Co	Kingston.
5971	Kingston Gas & Electric Co	Do.
5972	Edward R. Ladew Co. (Inc.)	Glen Cove.
5973	La Fargeville Electric Light Co	La Fargeville.
5974	Lake Shore Electric Co	Henderson.
6205	La Salle Electric Corporation	Niagara Falls.
5975	Lawrence Park Heat, Light & Power Co	Bronxville.
5976	Lebanon Valley Lighting Co. (Inc.)	Canaan.
5977	Le Roy Hydraulic Electric Gas Co	Le Roy.
5979	Lewiston & Lake Ontario Shore Power Co	Lewiston.
5981	Liberty Light & Power Co	Liberty.
5983	Livingston Manor Electric Co	Livingston Manor.
5984	Livingston-Niagara Power Co	Avon.
5985	Livonia Light & Heat Co	Whiting.

TABLE 100.—*Electric-power companies engaged in public service in the States in which the superpower zone is situated*—Con.

New York—Continued.

No.	Operating company.	Station.
5986	Lockport Light, Heat & Power Co.:	
	A	Race Street.
	B	Elm Street.
5987	Long Acre Electric Light & Power Co	103 Park Avenue, New York.
5988	Long Beach Power Co	Long Beach.
5990	Long Island Lighting Co.:	
	A	Amityville.
	B	Babylon.
	D	Northport.
	E	Sayville.
	F	Bay Shore.
	G	Huntington.
	H	Port Jefferson.
	J	Do.
5992	Lyons Falls Electric Light Plant	Lyons Falls.
5993	Macedon Electric Light Co	Macedon.
5994	Madrid Electric Light Co	Madrid.
5995	Malone Light & Power Co.:	
	A	High Falls.
	B	Do.
	C	Malone.
	D	Chasm Falls.
	E	Whittlesey.
5998	Marcellus Lighting Plant	Marcellus.
6000	Marion Power Co	Sodus.
6001	Massena Electric Light & Power Co	Potsdam.
6003	Mexico Electric Co	Mexico.
6005	Middleville Electric Light Co	Frisbieville.
6006	do	Middleville.
6006-1	Middleport Gas & Electric Light Co	Middleport.
6007	Millerton Electric Light Co	Millerton.
6008	Milling & Lighting Co	Brasher Falls.
6009	Mineville Light, Heat & Power Co	Mineville.
6010	Mohawk Hydro Electric Co	Ephrata.
6012	Montgomery Electric Light & Power Co	Canajoharie.
6013	Mooers Electric Light Co	Mooers.
6014	Moravia Electric Light, Heat & Power Co	Moravia.
6015	Morgan & Wyman Light & Power Co	Dover Plains.
6017	Mount Morris Illuminating Co	Mount Morris.
6018	Municipal electric plant	Akron.
6019	do	Arcade.
6021	do	Batavia.
6022	do	Bath.
6023	do	Bergen.
6024	do	Boonville.
6025	do	Brockton.
6026	do	Camden.
6028	do	Castile.
6029	do	Clifton Springs.
6030	do	Clinton.
6031	do	Delevan.
6033	do	Dunkirk.
6034	do	Fairport.
6035	do	Frankfort.
6036	do	Fredonia.
6037	do	Freeport.
6038	do	Greene.
6039	do	Green Island.
6040	do	Greenport.
6041	Groton Electric Power Corporation	Groton.
6043	Municipal electric plant	Hamilton.
6044	do	Herkimer.
6045	do	Holley.
6046	do	Ilion.
6047	do	Jamestown.
6048	do	Lake Placid.
6049	do	Little Valley.
6050	do	Marathon.
6051	do	Mayville.
6053	do	Mohawk.
6054	do	Newark Valley.
6056	do	Penn Yan.

TABLE 100.—*Electric-power companies engaged in public service in the States in which the superpower zone is situated*—Con.

New York—Continued.

No.	Operating company.	Station.
6057	Municipal electric plant	Philadelphia.
6058	.....do	Port Byron.
6059	.....do	Potsdam.
6060	.....do	Rockville Center.
6061	.....do	Rouses Point.
6062	.....do	Salamanca.
6063	.....do	Savannah.
6064	.....do	Sherburne.
6065	.....do	Silver Springs.
6066	.....do	Skaneateles.
6067	.....do	Solvay.
6069	.....do	Springville.
6070	.....do	Theresa.
6071	.....do	Tully.
6072	.....do	Tupper Lake.
6073	.....do	Union.
6074	.....do	Watkins.
6075	.....do	Wellsville.
6076	.....do	Westfield.
6078	Municipal Gas Co	Albany.
6079	Murray Electric Light & Power Co	Monticello.
6081	Nassau Light & Power Co	Glenwood.
6083	New Berlin Light & Power Co	New Berlin.
50074-1	New Fabric Cloth Co	Oswego.
6084	Newfane Electric Co	Newfane.
50074	Newfane Lumber & Manufacturing Co	Do.
6085	New Paltz Highland & Poughkeepsie Traction Co	Loyd.
6086	Newport Electric Light & Power Co	Newport.
6087	New York Central Railroad:	
	A	Glenwood.
	B	Port Morris.
6090	New York Edison Co.:	
	A	Duane Street.
	B	Waterside No. 1.
	C	Waterside No. 2.
	D	Kingsbridge.
5960	New York State Gas & Electric Corporation:	
	A	Ithaca.
	B	Norwich.
	C	Oneonta.
6093	New York State Railways, Rochester Lines:	
	A	Floatbridge.
	B	Canandaigua.
6097	New York & Long Island Traction Co	Rockville Center.
6098	New York & North Shore Traction Co	Douglaston.
6099	New York & Ontario Power Co	Waddington.
6101	New York & Queens Electric Light & Power Co	Astoria.
6103	Niagara Electric Service Corporation	Niagara Falls.
6105	Niagara Falls Gas & Electric Light Co	Do.
6106	Niagara Falls Power Co.:	
	A	Do.
	B	Hydraulic.
6108	Niagara, Lockport & Ontario Power Co.:	
	A	Salmon River.
	B	Auburn.
	C	Lyons.
	D	Minetto.
6109	Niagara & Erie Power Co	Buffalo.
6110	North Creek Electric Co	North Creek.
6111	Northern Adirondack Power Co	Ausable Chasm.
6112	Northern New York Utilities:	
	A	Black River.
	B	Effley Falls.
	C	Elmer Falls.
	D	South Edwards.
	E	Taylorville.
	F	Watertown.
	G	Belfort.
	H	Browns Falls.
6113	Northern Wayne Electric Light & Power Co	Wolcott.
6114	Northern Westchester Lighting Co	Ossining.
6116	North Syracuse Light & Power Co	North Syracuse.

TABLE 100.—*Electric-power companies engaged in public service in the States in which the superpower zone is situated*—Con.

New York—Continued.

No.	Operating company.	Station.
6118	Norwood Electric Light & Power Co.	Yaleville.
6118-1	Nuerd Paper Co. (Inc.)	Hadley.
6119	Nunda Electric Light Co.	Nunda.
6121	Ogdensburg Power & Light Co.	Ogdensburg.
6123	Olean Electric Light & Power Co.:	
	A	Franklinville.
	B	Olean.
6175	O'Neil & Co.	St. Regis Falls.
6126	Orange County Public Service Corporation:	
	A	Cuddebackville.
	B	Middletown.
	C	Port Jervis.
6127	Orange County Traction Co.	Newburgh.
6128	Orange & Rockland Electric Co.	Monroe.
6129	B. L. Orcutt & Sons (Inc.)	Dickinson Center.
6130	Oswegatchie Light & Power Co.:	
	A	Fowler.
	B	Hailesboro.
6131	Oswegatchie River Power Co.	South Edwards.
6132	Oswego River Power Transmission Co.	Syracuse.
50206-1	Oval Wood Dish Co.	Tupper Lake.
6133	Ovid Electric Co.	Taughannock Falls.
6134	Owego Light & Power Co.	Owego.
6135	Panama Power Co.	Panama.
6136	Parishville Electric Light Plant	Parrishville.
6137	Patchogue Electric Light Co.	Patchogue.
6138	Paul Smith's Electric Light & Power & Railroad Co.:	
	A	Franklin Falls.
	B	Keeses Mills.
	C	Saranac Lake.
	D	Union Falls.
6139	Peeksville Lighting & Railroad Co.	Peeksville.
6141	Pennsylvania Tunnel & Terminal Railroad Co.	Long Island City.
6142	Penn Yan & Lake Shore Railway	Park Landing.
6143	Peoples Gas & Electric Co.	Oswego.
6144	Perry Electric Light Co.:	
	A	Perry.
	B	Do.
6145	W. J. Phillips	Manlius.
6146	Phoenix Gas & Electric Co. (Inc.)	Syracuse.
6147	Plattsburg Gas & Electric Co.:	
	A	Indian Rapids.
	B	Plattsburg.
6148	Plattsburg Traction Co.	Do.
6149	Port Henry Light, Heat & Power Co.	Port Henry.
6152	Port Jervis Traction Co.	Port Jervis.
6153	Port Leyden Electric Light & Power Co.	Port Leyden.
6154	Potsdam Electric Light & Power Co.	Potsdam.
6158	Queensborough Gas & Electric Co.	Far Rockaway.
6159	Iroquois Utilities (Inc.)	Randolph.
6160	Red Hook Light & Power Co.	Bingham Mills.
6161	Rensselaer Falls Electric Light & Power Co.	Rensselaer Falls.
6162	Richmond Light & Railroad Co.	Livingston.
6163	Riddell Electric Light & Power Co.	Luzerne.
6164	Alfred Huntington	Ripley.
6165	Riverhead Electric Light Co.	Riverhead.
6166	Rochester Gas & Electric Corporation:	
	B	No. 2a.
	C	No. 26.
	D	No. 4.
	E	New No. 5.
	F	No. 6.
	G	No. 34.
	H	No. 35.
	I	No. 3.
	J	Littleville.
6167	Rochester & Manitou Railroad Co.	Rochester.
6167-1	Rochester & Syracuse Railroad Co. (Inc.)	Syracuse.
6168	Rockland Light & Power Co.:	
	A	Hillburn.
	B	Orangeburg.
6169	Rome Gas, Electric Light & Power Co.	Rome.
6171	Sag Harbor Electric Light & Power Co.	Sag Harbor.

TABLE 100.—*Electric-power companies engaged in public service in the States in which the superpower zone is situated*—Con.

New York—Continued.

No.	Operating company.	Station.
6173	St. Lawrence River Power Co.	Massena.
6174	St. Lawrence Transmission Co.	Potsdam.
6175	Sulham Manufacturing Co.	St. Regis Falls.
6178	Salem Light, Heat & Power Co.	Salem.
6180	Adirondack Power & Light Corporation	Johnsonville, etc.
6181	Schenectady Railway Co.	Schenectady.
6183	Schodack Light & Power Corporation	Castleton.
6184	Schuyler County Light & Power Co.	Watkins
6185	Scottsville Electrical Light & Gas Co.	Avon.
6188	Seeley Electric Co.	Spencer.
6189	Seneca River Power Co.	Baldwinsville.
50506	Setter Bros. Co.	Cattaraugus.
6190	Sherman Electric Light Co.	Sherman.
6193	Shushan Electric Light Plant	Shushan.
6194	Silver Creek Electric Co.	Silver Creek.
6195	Sinclairville Electric Light Plant	Sinclairville.
6195–1	Snell Power Co.	Higley Falls.
6196	Sodus Gas & Electric Light Co.	Sodus.
6197	Solsville Electric Light & Power Co.	Solsville.
6199	Southern Dutchess Gas & Electric Co.	Beacon.
6199–1	Southern New York Power Co.:	
	A	Walton.
	B	Stilesville.
6200	Southern New York Power & Railway Corporation:	
	A	Colliers.
	B	Hartwick.
6202	Standard Light, Heat & Power Co.	Sidney.
6204	Charles H. Stokes Electric Plant	Kerhonkson.
6205	La Salle Electric Corporation	Niagara Falls.
6207	Suffolk Light, Heat & Power Co.	Southampton.
6209	Syracuse Lighting Co.	Syracuse.
6211	Syracuse & Suburban Railroad Co.	Edward Falls.
6212	Theresa Electric Light Co.	Theresa.
6215	Ticonderoga Electric Light & Power Co.	Ticonderoga.
50712	Ticonderoga Pulp & Paper Co.	Do.
6217	Treadwell Electric Light Plant	Treadwell.
6218	Tri-County Light & Power Co.	Gilboa.
6219	Troy Gas Co.	Troy.
6220	Troy & New England Railway Co.	Albany.
6221	Tuxedo Electric Light Co.	Tuxedo Park.
6222	Twin State Gas & Electric Co.	Hoosick Falls.
6223	Tyler Light & Power Co.	Vernon.
6224	Ulster Electric Light, Heat & Power Co.	Saugerties.
50762	Union Bag & Paper Co.:	
	A	Bakers Falls.
	C	Fenimore.
	F	Moreau.
6225	Union Electric Co.	Whitney Point.
6227	Union Springs Light & Power Co.	Union Springs.
6228	United Electric Light & Power Co.	New York City.
6229	United Gas, Electric Light & Fuel Co.	Hudson Falls.
6230	United Traction Co.:	
	A	Albany.
	B	Troy Falls.
	C	West Sand Lake.
6231	Upper Hudson Electric & Railroad Co.:	
	A	Coxsackie.
	B	Catskill.
	C	Cairo.
	D	Hunter.
6232	Utica Gas & Electric Co.:	
	A	Dolgeville.
	D	Trenton Falls.
	F	Utica.
	G	Little Falls.
6234	Vestal Lighting Co.	Vestal.
6235	Wadhams & Westport Electric Light & Power Co.:	
	A	Wadhams.
	B	Do.
6236	Wallkill Transit Co.	Mechanicstown.
6237	Wallkill Valley Electric Light & Power Co.	Walden.
48985	Warren Curtis Manufacturing Co. (Inc.)	Corinth.
6239	Warrensburgh Electric Light Works	Warrensburgh.

TABLE 100.—*Electric-power companies engaged in public service in the States in which the superpower zone is situated*—Con.

New York—Continued.

No.	Operating company.	Station.
6240	Warsaw Gas & Electric Co.	Warsaw.
6242	Waterville Gas & Electric Co.	Waterville.
6242-1	Wayland-Steuben Power Co.	Wayland.
6243	Waverly, Sayre & Athens Traction Co.	Waverly.
6244	Wayland Light & Power Co. (Inc.)	Wayland.
6242-1	Wayland-Steuben Power Co.	Do.
6245	Wayne Power Co.	Sodus.
6246	West Branch Light & Power Co.:	
	A	Stamford.
	B	Kortright.
6248	Westchester Lighting Co.	New Rochelle.
6250	Western New York Electric Co.	Jamestown.
6251	Western New York Utilities Co.:	
	A	Medina.
	B	Waterport.
	C	Medina.
6252	Western New York & Pennsylvania Traction Co.	Ceres.
6252-1	Western Vermont Power & Light Co.	Carvers Falls.
6254	West Winfield Electric Co.	West Winfield.
50946	Witherbee-Sherman Co.:	
	A	Port Henry.
	B	Mineville.
6256	Worcester Electric Light Plant	Worcester.
6257	Wyantskill Hydro-Electric Co.	Wyantskill.
6258	Yates Electric Light & Power Co.	Seneca Mills.
6258-1	Yonkers Electric Light & Power Co.	New York City.
48834	A. C. Cheney Piano Action Co.	Castleton.
48895	Warren Curtis Manufacturing Co. (Inc.)	Corinth.
49143	Endicott, Johnson & Co.	Johnson City.
49275	General Electric Co.	Schenectady.
49320	Gould Paper Co.	Lyons Falls.
50074	Newfane Lumber & Manufacturing Co.	Newfane.
50074-1	New Fabric Cloth Co.	Oswego.
50206	Oval Wood Dish Co.	Tupper Lake.
50256-1	John Dunlop's Sons	Phoenix.
50506	Setter Bros. Co.	Cattaraugus.
50712	Ticonderoga Pulp & Paper Co.	Ticonderoga.
50762	*See* Union Bag & Paper Co.	Bakers Falls, etc.
50946	*See* Witherbee-Sherman Co.	Port Henry, etc.

Pennsylvania.

7500	Abington Electric Co.	Laplume.
7502	Allegheny Valley Light Co.	Creighton.
7503	Allegheny Valley Street Railway Co.	Pittsburgh.
7504	Allen Street Railway Co.	Bethlehem.
7505	Allentown & Reading Traction Co.	Reading.
7506	Altoona & Logan Valley Electric Railway Co.	Altoona.
7507	Ambler Electric Light, Heat & Motor Co.	Ambler.
7508	Annville & Palmyra Electric Light Co.	Annville.
7509	Anthracite Power Co.	Hazleton.
7510	Ardmore & Llanerch Street Railway Co.	Upper Darby.
7510-1	Arendtsville Roller Mills	Arandtsville.
7510-2	Bangor Electric Co.	Bangor.
7511	Barnesboro Spangler Electric Light Co.	Barnesboro.
7513	Bear Lake Electric Light Plant	Bear Lake.
7514	Beaver County Light Co.	Pittsburgh.
7515	Beaver Springs Electric Light Co.	Beaver Springs.
7516	Beaver Valley Traction Co.	New Brighton.
7517	Bedford Electric Light, Heat & Power Co.	Bedford.
7517-1	Bala & Merion Electric Co.	Philadelphia.
7518	Benton Hydroelectric Co.:	
	A	Benton.
	B	Hydroelectric.
7519	Berkshire Electric Co.	Sinking Spring.
7520	Berwich & Nescopeck Street Railway Co.	Berwick.
7522	Bethlehem & Nazareth Passenger Railway Co.	Bethlehem.
7523	Big Spring Electric Co.	Newville.
7524	Birdsboro Electric Co.	Birdsboro.
7526	Blossburg Electric Light & Power Co.	Blossburg.
7527	Blue Mountain Electric Co.	Bethel.

TABLE 100.—*Electric-power companies engaged in public service in the States in which the superpower zone is situated*—Con.

Pennsylvania—Continued.

No.	Operating company.	Station.
7528	Blue Ridge Traction Co.	Danielsville.
7529	Boiling Springs Electric Light Co.	Boiling Springs.
7530	Bolivar Light, Heat & Power Co.	Bolivar.
7531	Boyertown Electric Co.	Boyertown.
7533	Bradford Electric Co.	Bradford.
7534	Brownstown Electric Light, Heat & Power Co.	Brownstown.
7764	Bucks County Electric Co.	Doylestown.
7535	Buffalo & Lake Erie Traction Co.	Erie.
7538	Canton Illuminating Co.	Canton.
7539	Mauch Chunk & Lehighton Transit Co.	Mauch Chunk.
7540	Carlisle Gas & Water Co.:	
	A	Hydroelectric.
	B	Steam.
7540-1	Carpenter Electric Co.	Meadville.
7541	Center Electric Co.	Howard.
7542	Centre & Clearfield Railway Co.	Phillipsburg.
7543	Chambersburg, Greencastle & Waynesboro Street Railway Co.	Waynesboro.
7544	Chambersburg & Gettysburg Electric Railway Co.	Chambersburg.
7545	Chambersburg & Shippensburg Railway Co.	Do.
7545-1	Cheltenham Electric Light, Heat & Power Co.	Philadelphia.
7545-2	Chanceford Electric Light & Power Co.	Delta.
7546	Chester County Light & Power Co.	Kennett Square.
7548	Chester Valley Electric Co.	Coatesville.
7549	Chester & Philadelphia Railway	Philadelphia.
7549-1	Cheswick Power Co.	Colfax.
7550	Christiana & Coatesville Street Railway	Lancaster.
7551	Citizens Electric Co.	Williamsport.
7552	Citizens Electric Co.	Lewisburg.
7553	Citizens Electric Light & Power Co.	Hughesville.
7555	Citizens Light, Heat & Power Co.	Meyersdale.
7556	Citizens Light & Power Co.	Oil City.
7557	Citizens Traction Co.:	
	A	Do.
	B	Franklin.
7558	Clairton Street Railway Co.	Pittsburgh.
7559	Clarion Electric Co.	Clarion.
7560	Cleveland & Erie Railway Co.	Girard.
7561	Clymer Power Co.	Raubsville.
7562	Coalport Light, Heat & Power Co.	Coalport.
7565	Conestoga Traction Co.	Lancaster.
7752	J. W. Conner & Sons	Orangeville.
57543-1	Consolidation Coal Co.	Jenner.
7562-2	Coopersburg Electric Light, Heat & Power Co.	Coopersburg.
7566	Corry City Electric Light Co.	Corry.
7568	Counties Gas & Electric Co.:	
	B	Norristown.
	C	Wayne.
7569	Cresson Electric Light Co.	Cresson.
7570	Cumberland Railway	Carlisle.
7572	Danville & Sunbury Transit Co.	Danville.
7573	Deal Electric Light & Power Plant	Cooks Mills.
7574	Delaware County Electric Co.:	
	A	Beacon.
	B	Chester.
7575	Delaware County & Philadelphia Electric Railway Co.	Clifton Heights.
7576	Delaware Water Gap Light Plant	Delaware Water Gap.
7576-1	Delta Electric Light Co.	Delta.
7577	Delta Electric Power Co.	Do.
7578	Delta Water Power Co.	Do.
7579	Dillsburg Light, Heat & Power Co.	Dillsburg.
7581	DuBois Electric & Traction Co.	Du Bois.
7582	Dunbar Electric Co.	Dunbar.
7583	Duquesne Light Co.:	
	A	Brunots Island.
	B	Rankin.
	C	Twentieth Street.
	D	Thirteenth Street.
	E	Glenwood.
	F	Phipps.
	K	Millvale.
7584	Duquesne & Dravosburg Street Railway Co.	Duquesne.
7585	Eaglesmere Light Co.	Eaglesmere.
7586	East End Passenger Railway Co.	Williamsport.

TABLE 100.—*Electric-power companies engaged in public service in the States in which the superpower zone is situated*—Con.

Pennsylvania—Continued.

No.	Operating company.	Station.
7587	Eastern Pennsylvania Light, Heat & Power Co.:	
	A	Ashland.
	B	Frackville.
	C	Palo Alto.
7588	Eastern Pennsylvania Railway Co	Pottsville.
7589	Easton Transit Co	Allentown.
7590	East Pennsylvania Gas & Electric Co	Bristol.
7591	Ebensburg Light, Heat & Power Co	Ebensburg.
7592	Eckels Light, Heat & Power Co	Conneautville.
7593	Edison Electric Co	Engleside.
7595	Edison Light & Power Co	York.
7882	William Ellsworth Electric Co	Wyalusing.
7596	Ephrata & Lebanon Street Railway Co	Lebanon.
7597	Ephrata & Lebanon Traction Co	Pittsburgh.
7598	Erie County Electric Co.:	
	A	Erie No. 1.
	B	Erie No. 2.
7599	Erie Lighting Co.:	
	A	Front Street.
	B	Peach Street.
7600	Everett Light, Heat & Power Co	Everett.
7601	Excelsior Electric Light, Power & Gas Co	Philadelphia.
7602	Fairchance & Smithfield Traction Co	Uniontown.
7603	Fairmount Park Transportation Co	Belmont.
7605	Frankford, Tacony & Holmesburg Street Railway Co	Philadelphia.
7607	Gallitzin Electric Light Co	Cresson.
7608	Garret Electric Light, Heat & Power Co	Garrett.
7608-1	Harry E. Geiser	Montgomery Mills.
7609	Gettysburg Electric Co	Gettysburg.
7610	Gettysburg Railway Co	Do.
7612	Glen Rock Electric Light & Power Co	Glen Rock.
7615	Greencastle Light, Heat, Fuel & Power Co	Greencastle.
7616	Halfpenny & Grove	Mifflinburg.
7617	Hamburg Gas & Electric Co	Hamburg.
7617-1	Hanover Light, Heat & Power Co	Hanover.
7618	Hanover & McSherrytown Street Railway Co	Do.
7618-1	Harmony Electric Co	Harmony.
7619	Harrisburg Light & Power Co.:	
	A	Cedar Street.
	B	Ninth Street.
7620	Harrisburg Railways Co	Harrisburg.
7622	Hastings Electrical Co	Hastings.
7623	Hershey Transit Co	Hershey.
7624	Highland Grove Traction Co	McKeesport.
7624-1	Hinkletown-Conestoga Valley Electric Co	Hinkletown.
7625	Home Electric Co	Coudersport.
7627	Home Electric Light & Steam Heating Co	Tyrone.
7628	Homestead & Mifflin Street Railway Co	Homestead.
7629	Honesdale Consolidated Light, Heat & Power Co	Honesdale.
7630	Houtzdale Electric Light, Heat & Power Co	Houtzdale.
7631	Hummelstown Water & Power Co	Harrisburg.
7632	Huntingdon, Lewistown & Juniata Valley Traction Co	Huntingdon.
7633	Hyndman Electric Light, Heat & Power Co	Hyndman.
7634	Indiana County Street Railway Co	Indiana.
7636	Intercourse Electric Light, Heat & Power Co	Intercourse.
7637	Irwin-Herminie Traction Co	Irwin.
7639	Jefferson Electric Co.:	
	A	Punxsutawney.
	B	Reynoldsville.
7640	Jersey Shore Traction Co.:	
	A	Florence.
	B	Rathmel Junction.
7640-1	Jersey Shore Electric Co	Jersey Shore.
7641	Jersey Shore Electric Street Railway Co	Do.
7642	Jersey Shore & Antes Fort Railroad Co	Do.
7643	Johnsonburg Light & Power Co	Johnsonburg.
7644	Johnstown Traction Co	Johnstown.
2800	Keystone Electric Service Corporation:	
	A	Ridgway.
	B	Kane.
7647	Kittanning & Leechburg Railways Co	Pittsburgh.
7647-1	Lackawanna Light Co	Scranton.
7648	Lackawanna & Wyoming Valley Power Co	Do.

TABLE 100.—*Electric-power companies engaged in public service in the States in which the superpower zone is situated*—Con.

Pennsylvania—Continued.

No.	Operating company.	Station.
7649	Lancaster County Railway & Light Co	Lancaster.
7650	Lancaster Electric Light, Heat & Power Co.:	
	A	Rock Hill.
	B	Slackwater.
7652	Lancaster & York Furnace Street Railway Co	Philadelphia.
7653	Langhorne Electric Light & Power Co	Langhorne.
7658	Lehighton Electric Light & Power Co	Lehighton.
7659	Lehigh Traction Co	Hazelton.
7661	Lehigh Valley Transit Co	Allentown.
7662	Lewisburg, Milton & Watsontown Passenger Railway Co	Milton.
7663	Lewistown & Reedsville Electric Railway Co	Lewistown.
7664	Lilly Electric Light, Heat & Power Plant	Lilly.
7665	Lock Haven Electric Light & Power Co	Lock Haven.
7667	Luzerne County Gas & Electric Co	Plymouth.
7668	Lycoming Edison Co	Williamsport.
7669	Lykens Valley Light & Power Co.:	
	A	Wiconisco.
	B	Williamstown.
7670	Macungie Electric Light, Heat & Power Co	Macungie.
7672	Mansfield Electric Co	Mansfield.
7539	Mauch Chunk & Lehighton Transit Co	Mauch Chunk.
7674	Mauch Chunk Heat, Power & Electric Light Co	Do.
7675	Media, Glen Ridle & Rockdale Electric Street Railway Co	Media.
7676	Mercer County Light, Heat & Power Co	Greenville.
7677	Mercersburg, Lehmasters & Markes Electric Co	Markes.
7678	Metropolitan Edison Co.:	
	A	Lebanon.
	B	Klapperthal.
	C	West Reading.
7679	Meyersdale Electric Light, Heat & Power Co	Meyersdale.
7680	Middleburg Light, Heat & Power Co	Clearfield.
7681	Midland Electric Light & Power Co	Pittsburgh.
7682	Juniata Public Service Co	Millersburg.
7683	Montgomery Transit Co	Norristown.
7684	Montgomery & Muncy Electric Light, Heat & Power Co	Montgomery.
7685	Montoursville Electric Light Co	Montoursville.
7686	Montoursville Passenger Railway Co	Do.
7688	Mount Holly Light, Heat & Power Co	Mount Holly Springs.
7688-1	Mount Jewett Electric Light Co	Mount Jewett.
7689	Mount Penn Gravity Railroad Co	Reading.
7690	Municipal electric plant	Allegheny.
7691	do	Aspinwall.
7691-1	do	Bally.
7691-2	do	Bechtelsville.
7692	do	Berlin.
7693	do	Catawissa.
7694	do	Chambersburg.
7695	do	Conemaugh.
7696	do	Confluence.
7697	do	Coraopolis.
7698	do	Danville.
7699	do	Duncannon.
7700	do	Easton.
7701	do	Ellwood City.
7702	do	Emporium.
7703	do	Ephrata.
7704	do	Etna.
7705	do	Ford City.
7707	do	Goldsboro.
7708	do	Grove City.
7708-1	do	Hatfield.
7709	do	Kutztown.
7710	do	Lansdale.
7711	do	Meadville.
7712	do	Media.
7713	do	Middletown.
7714	do	Mifflinburg.
7716	do	New Freedom.
7717	do	New Wilmington.
7718	do	Norristown.
7719	do	Olyphant.

TABLE 100.—*Electric-power companies engaged in public service in the States in which the superpower zone is situated*—Con.

Pennsylvania—Continued.

No.	Operating company.	Station.
7720	Municipal electric plant	Peckville.
7721	.....do	Pennsburg.
7722	.....do	Perkasie.
7723	.....do	Pitcairn.
7724	.....do	Quakertown.
7724-1	.....do	Royalton.
7725	.....do	St. Clair.
7726	.....do	Schuylkill Haven.
7727	.....do	Sharpsburg.
7728	.....do	Souderton.
7729	.....do	Tarentum.
7730	.....do	Titusville.
7730-1	.....do	Wampum.
7731	.....do	Weatherly.
7731-1	.....do	Womelsdorf.
7732	Neversink Mountain Railway Co	Reading.
7733	Newcastle Electric Co	Newcastle.
7734	Newcastle & Lowell Railway Co	Youngstown.
7735	New Holland, Blue Ball & Terre Hill Street Railway Co	Lancaster.
7736	New Hope Electric Co	New Hope.
7737	New Kingstown Electric Light, Heat & Power Co	New Kingstown.
7738	Newmanstown Electric Light & Power Co	Lebanon.
7740	Nicholson Light, Heat & Power Co	Nicholson.
7741	Norristown Transit Co	Philadelphia.
7743	Northampton Traction Co	Easton.
7748	Northwestern Electric Service Co	Erie.
7749	Northwestern Pennsylvania Railway Co	Meadville.
7750	Oakdale & McDonald Street Railway Co	Pittsburgh.
7751	Oley Valley Railway Co	Reading.
7752	J. W. Conner & Sons	Orangeville.
7753	Oxford Electric Co	Oxford.
7754	Panther Valley Electric Co	Lansford.
7755	Patterson Heights Street Railway Co	Beaver Falls.
7756	Paupack Electric Co	Hawley.
7757	Penn Central Light & Power Co.:	
	C	Eighteenth Street, Altoona.
	D	Twentieth Street, Altoona.
7758	Penn Central Power & Transmission Co	Williamsburg.
7760	Penn Hydro-Electric Co	Warrior Ridge.
7761	Penn Public Service Corporation:	
	A	Blairsville.
	B	Clearfield.
	C	Philipsburg B.
	E	Indiana.
	F	Philipsburg A.
	G	Broad Street.
	H	Vine Street.
	J	Somerset.
	K	Rockwood.
7763	Pennsylvania Light & Power Co	Pittsburgh.
7764	Bucks County Electric Co	Doylestown.
7764-1	Pennsylvania-New Jersey Railway Co	Yardley.
7765	Pennsylvania Power Co	Ellwood City.
7765-1	Pennsylvania Power & Light Co.:	
	A	Harwood Mines.
	B	Hauto.
	C	Irondale.
	D	Milton.
	E	Mount Carmel.
	F	Selinsgrove.
	G	Shamokin.
	H	Sunbury.
7766	Pennsylvania Railroad	Philadelphia.
7767	Pennsylvania Utilities Co.:	
	B	Dock Street.
	D	South Side No. 1.
	F	East Stroudsburg.
7768	Pennsylvania Water & Power Co	Holtwood.
7769	Pennsylvania & Maryland Street Railway Co	Boynton.
7771	Peoples Street Railway Co. of Nanticoke & Newport	Wanamie.
7773	Philadelphia Electric Co.:	
	A	Schuylkill No. 1.
	B	Carpenter.

TABLE 100.—*Electric-power companies engaged in public service in the States in which the superpower zone is situated*—Con.

Pennsylvania—Continued.

No.	Operating company.	Station.
7773	Philadelphia Electric Co.—Continued.	
	C	Edison.
	D	Callowhill.
	G	Tacony.
	H	Delaware.
	K	Schuylkill.
7774	Philadelphia Hydro-Electric Co	Manayunk.
7775	Philadelphia Railways Co	Philadelphia.
7776	Philadelphia Rapid Transit Co.:	
	A	Beach Street.
	B	Market Street.
	C	Wyoming Avenue.
	D	Upper Darby.
	E	Mount Vernon Street.
7777	Philadelphia Suburban Gas & Electric Co.:	
	C	West Chester.
	D	Cromby.
7778	Philadelphia & Easton Electric Railway Co	Doylestown.
7779	Philadelphia & Garrettford Street Railway Co	Upper Darby.
7780	Philadelphia & West Chester Traction Co.:	
	A	Ridley Creek.
	B	Llanerch.
7781	Philadelphia & Western Railway Co	Upper Darby.
7782	Phoenixville, Valley Forge & Strafford Electric Railway Co	Phoenixville.
7783	Phoenix Water Power Co	Do.
7785	Pine Grove Electric Light, Heat & Power Co	Pine Grove.
7786	Pittsburgh, Harmony, Butler & Newcastle Railway Co	Harmony.
7788	Pittsburgh Railways Co	Pittsburgh.
7789	Pittsburgh & Allegheny Valley Traction Co	Do.
7790	Pittsburgh & Beaver Street Railway Co	Do.
7791	Pittsburgh, Mars & Butler Railway	Renfrew.
7792	Plymouth & Larksville Railway Co	Wilkes-Barre.
7793	Pottstown & Phoenixville Railway Co	Philadelphia.
7793-1	Prospect Rock Light & Power Co	Georgetown.
7794	Railroad Electric Light & Power Co	Railroad.
7795	Raystown Water Power Co.:	
	A	Main.
	B	Auxiliary.
7796	Reading Transit & Light Co	Reading.
7797	Redbank Electric Co	New Bethlehem.
7798	Renovo Edison Light, Heat & Power Co	Renovo.
7800	*See* Keystone Electric Service Corporation	Ridgway, etc.
7801	Ringtown Electric Light, Heat & Power Co	Ringtown.
7802	Roaring Spring Light, Heat & Power Co	Roaring Spring.
7803	Rockwood Electric Co	Rockwood.
7804	St. Marys Electric Light Co	St. Marys.
7805	Sayre Electric Co	Sayre.
7805-1	Schuylkill Electric Co	Girardville.
7806	Schuylkill Gas & Electric Co	Allentown.
7807	Schuylkill Light, Heat & Power Co	Girardville.
7808	Schuylkill Railway Co	Do.
7809	Schuylkill Valley Traction Co	Collegeville.
7811	Scranton Electric Co.:	
	A	Pittston.
	B	Suburban.
	C	Linden Street.
7812	Scranton Railway Co	Scranton.
7813	Scranton & Binghamton Railroad Co	Dalton.
7814	Shamokin & Edgewood Electric Railway Co	Shamokin.
7815	Shamokin & Mount Carmel Transit Co	Mount Carmel.
7816	Sharon & New Castle Street Railway Co	Youngstown.
7817	Shenango Valley Electric Light Co	Sharon.
7818	Shermans Valley Light, Heat & Power Co	Landisburg.
7819	Shippenburg Gas & Electric Co.:	
	A	Roxbury.
	B	Shippensburg.
	C	Lurgan.
7820	Slate Belt Electric Street Railway Co	Penn Argyl.
7820-1	Solar Electric Co	Brookville.
7821	South Bethlehem & Saucon Street Railway Co	South Bethlehem.
7822	Southern Cambria Railway Co	Brookdale.
7823	Southern Pennsylvania Traction Co	Chester.

TABLE 100.—*Electric-power companies engaged in public service in the States in which the superpower zone is situated*—Con.

Pennsylvania—Continued.

No.	Operating company.	Station.
7825	South Side Passenger Railway Co	Williamsport.
7827	State Center Electric Co	Milesburg.
7828	Strasburg Electric Light, Heat & Power Co	Strasburg.
7829	Stroudsburg Electric Light & Power Co	Allentown.
7830	Stroudsburg Traction Co	Stroudsburg.
7832	Sunbury & Susquehanna Railway	Rolling Green.
7833	Susquehanna County Light & Power Co.:	
	A	Oakland.
	B	Lanesboro.
7833-1	Susquehanna Traction Co	Lock Haven
7834	Tarentum, Brackenridge & Butler Street Railway Co	Tarentum.
7834-1	Tatamy Light, Heat & Power Co	Tatamy.
7835	Titusville Light & Power Co	Titusville.
7836	Titusville Traction Co	Do.
7837	Titusville & Cambridge Railroad Co	Do.
7838	Towanda Electric Illuminating Co	Towanda.
7839	Trenton, Bristol & Philadelphia Street Railway Co	Croydon.
7840	Treverton Electric Light & Power Co	Treverton.
7841	Tri-County Electric Co	Lincoln.
7842	Troy Electric Light, Heat & Power Co	Troy.
7843	Tunkhannock Electric Co	Tunkhannock
7845	Union City Electric Light Co	Union City.
7846	United Electric Co	Lemoyne.
7848	United Electric Light Co	Wilmerding.
7849	United Light, Heat & Power Co	Stoyestown.
7851	United Lighting Co	Albion.
7852	Vallamont Traction Co	Williamsport.
7853	Vandergrift Electric Light & Power Co	Vandergrift.
7854	Warren Light & Power Co	Warren.
7855	Warren Street Railway Co	Stoneham.
7856	Warren & Jamestown Street Railway Co	Warren.
7857	Waterford Electric Light Co	Waterford.
7858	Waynesburg & Blackville Street Railway Co	Waynesburg.
7858-1	Waynesboro Electric Co	Waynesboro.
7859	Webster, Monessen, Belle Vernon & Fayette City Street Railway Co.	Charleroi.
7860	Weimer Electric Light & Power Co	Mount Gretna.
7861	Wellsboro Electric Co	Wellsboro.
7862	West Chester, Kennett & Wilmington Electric Railway Co	Kennett Square.
7863	Westmoreland County Railway Co	Pittsburgh.
7866	West Penn Power Co.:	
	A	Ohiopyle.
	B	Connellsville.
	C	Ligonier.
	E	Washington.
	F	Waynesburg.
	G	Kittanning.
	H	Butler.
	J	Springdale.
7867	West Penn Railways Co	Pittsburgh.
7868	West Side Electric Street Railway Co	Charleroi.
7870	Whitehall Street Railway Co	Allentown.
7871	White Haven Electric Illuminating Plant	White Haven.
7872	White Oak Light, Heat & Power Co	Hollsopple.
7873	Wilkes-Barre Co.:	
	A	North River Street
	B	Bennett Street
7874	Wilkes-Barre Railway Co	Wilkes-Barre.
7876	Wilkes-Barre & Hazleton Railway Co	St. Johns.
7877	Wilkes-Barre & Wyoming Valley Traction Co	Wilkes-Barre.
7878	Williamsport Passenger Railway Co	Williamsport.
7879	Windber Electric Co	Windber.
7880	Woodlawn & Southern Street Railway	Pittsburgh.
7881	Wrightsville Light & Power Co	Wrightsville.
7882	William Ellsworth Electric Co	Wyalusing.
7882-1	Yeagertown Water Power Co	Yeagertown.
7883	Yorkhaven Water & Power Co	Yorkhaven.
7884	York Railways Co	York.
7885	Zelienople Light & Power Co	Zelienople.

TABLE 100.—*Electric-power companies engaged in public service in the States in which the superpower zone is situated*—Con.

Rhode Island.

No.	Operating company.	Station.
7900	*See* Eastern Massachusetts Street Railway Co	Portsmouth, etc.
7901	Blackstone Valley Gas & Electric Co.:	
	B	Pawtucket.
	C	Woonsocket.
	D	Jencks Lane.
7902	Bristol County Gas & Electric Co	Bristol.
7900	Eastern Massachusetts Street Railway Co.:	
	A	Portsmouth.
	B	Newport.
7904	Municipal electric plant	Pascoag.
7905	Narragansett Electric Lighting Co	Providence.
7906	Narragansett Pier Electric Light & Power Co	Wakefield.
7909	Providence, Warren & Bristol Railroad Co	Warren.
7910	Rhode Island Co	Providence.
7911	Rhode Island Power Transmission Co	Worcester.
7911-1	F. A. Sayles	Samoset.
7913	Tiverton Electric Light Co	Tiverton.
7915	Westerly Light & Power Co	Westerly.
7914	West Gloucester Light & Power Co	Putnam
7916	Wickford Light & Water Co	Wickford.

Vermont.

8700	William F. Allen Light Co	Canaan.
8701-1	Bellows Falls Electric Co.:	
	A	Rockingham.
	B	Water.
8703	W. E. Benson	Weston.
8703-1	Berkshire Street Railway Co	New Haven.
8705	Bradford Electric Lighting Co	Bradford.
8706	Bridgewater Electric Co	Bridgewater.
8708	Burlington Light & Power Co.:	
	A	Colchester.
	B	Essex Junction.
8708-1	Burlington Traction Co	Vergennes.
8709	Chester Water & Light Co	Chester.
8712	*See* Vermont Hydro-Electric Corporation	Cavendish, etc.
8713	Connecticut River Power Co	Vernon.
8715	Eastern Vermont Public Utilities Corporation:	
	A	Barnet.
	B	Groton.
	C	Do.
	D	Ryegate.
	E	Wells River.
	F	Joes Pond.
8716	Electric Light & Power Co	South Londonderry.
8718	Fall Mountain Electric Co	Forest.
8719	Frontier Electric Co	North Troy.
8720	Glover Electric Light Plant	Glover.
8721	Hortonia Power Co.:	
	A	Bethel.
	B	Bristol.
	C	Gaysville.
	D	Bethel.
	F	Hortonville.
	G	Brandon.
	H	Salisbury.
	J	Silver Lake.
	L	Middlebury.
	M	Waybridge.
8723	Island Pond Electric Co	West Charleston.
8724	Jones & Lamson Power Co	Perkinsville.
8726	B. J. Kendall Co	Enosburg Falls.
8727	Lunenburg Manufacturing Co	Lunenburg.
8728	Lyman Falls Power Co	Bloomfield.
8731	Middlebury Electric Co	Middlebury.
8733	Missisquoi Lighting Co	Highgate.
8734	Missisquoi Pulp Co	Sheldon.

TABLE 100.—*Electric-power companies engaged in public service in the States in which the superpower zone is situated*—Con.

Vermont—Continued.

No.	Operating company.	Station.
8735	Montpelier & Barre Light & Power Co.:	
	A	Berlin.
	B	Middlesex.
	C	Moretown.
	D	Montpelier.
	E	Moretown.
	F	North Duxbury.
	G	Montpelier.
8736	Mount Mansfield Electric Railroad Co	Stowe.
8737	Municipal electric plant	West Charleston.
8738	.....do	Burlington.
8740	.....do	Enosburg Falls.
8741	.....do	Wolcott.
8742	.....do	Hyde Park.
8743	.....do	Johnson.
8744	.....do	Ludlow.
8745	.....do	Lyndonville.
8746	.....do	Cadys Falls.
8747	.....do	Northfield.
8748	.....do	Orleans.
8749	.....do	Readsboro.
8750	.....do	Highgate.
8751	.....do	West Burke.
8752	Nelson & Hall Co.:	
	A	Samsonville.
	B	Montgomery Center.
8752-1	New England Power Co	Readsboro.
8753	Newport Electric Light Co	Newport.
8754	Pittsford Power Co	Pittsford.
8755	Powers Electric Co	Richmond.
8756	Public Electric Light Co.:	
	A	St. Albans.
	B	Fairfax Falls.
8758	Reading Light & Power Co	Felchville.
8762	Rochester Electric Light & Power Co	Rochester.
8763	Royalton Power Co	Royalton.
8764	Rutland Railway Light & Power Co	Rutland.
8765	St. Albans & Swanton Traction Co	St. Albans.
8765-1	Sheldon Light & Power Co	Sheldon Springs.
8766	W. J. Smith	Sheffield.
8767	Springfield Electric Railway Co	Springfield.
8768	Stamford Light, Heat & Power Co	North Adams, Mass.
8769	Sweat-Comings Co	Richford.
9771	Twin State Gas & Electric Co.:	
	A	Bennington.
	B	St. Johnsbury No. 1.
	C	St. Johnsbury No. 2.
	D	St. Johnsbury No. 3.
	E	St. Johnsbury No. 4.
	F	West Dummerston.
	G	St. Johnsbury No. 5.
8712	Vermont Hydro-Electric Corporation:	
	A	Cavendish.
	B	Mendon.
8774	Vermont Marble Co.:	
	A	Beldens.
	B	Center Rutland.
	C	Florence.
	D	Huntington Falls.
	E	Proctor.
	F	West Rutland.
8774-1	Vermont & Quebec Power Corporation	Stevens Mill.
8775	Vermont Soapstone Co	Perkinsville.
8777	Wilmington Electric Light Co	Wilmington.
8778	Windsor Electric Light Co.:	
	A	Windsor No. 1.
	B	Windsor No. 2.
8780	Woodbury Granite Co.:	
	A	Mackville.
	B	Do.
8781	Woodstock Electric Co	Taftsville.

TABLE 100.—*Electric-power companies engaged in public service in the States in which the superpower zone is situated*—Con.

Virginia.

No.	Operating company.	Station.
8800	Abingdon Utilities Co	Abingdon.
8801	Alexandria County Lighting Co	Alexandria.
8802	Altavista Light & Power Corporation	Altavista.
8803	Appalachian Power Co.:	
	A	No. 2, Byllesby.
	B	No. 4, Byllesby.
	C	Glen Lyn.
	D	Clinchfield.
8804	Arlington Electric Co	Alexandria.
8806	Bloxom Electric Light Co	Bloxom.
8807	Shenandoah Traction Co	Staunton.
8808	Braddock Light & Power Co	Roslyn.
8809	Charlottesville & Albemarle	Charlottesville.
8810	Chatham Light & Power Co	Chatham.
8812	Nottoway Light & Power Co	Crewe.
8813	Culpeper Light & Ice Co	Culpeper.
8814	Damascus Light & Power Co	Damascus.
8815	Danville Traction & Power Co	Danville.
8816	Delmarvia Light, Heat & Refining Corporation	Chincoteague Island.
8817	Electric Light & Power Co	Remington.
8818	Electric Transmission Company of Virginia:	
	A	Big Stone Gap.
	B	Pocket.
8819	Emporia Hydro-Electric Power Corporation	Emporia.
8820	Exmore Light & Power Co	Exmore.
8822	Grundy Light & Power Co	Grundy.
8825	J. H. & C. T. Hopkins	Parksley.
8826	Halifax Hydro-Electric Co	Houston.
8827	Independence Electric & Milling Co	Independence.
8828	Leesburg Electric Co.:	
	A	Steam.
	B	Goose Creek.
8829	Light & Power Co. of Rockymount	Rockymount.
8830	London Light & Power Co	Purcellville.
8831	Lynchburg Traction & Light Co.:	
	A	Reusen.
	B	Blackwater.
8832	J. D. Manor & Co	New Market.
8833	Monterey Garage & Light Co	Monterey.
8834	Municipal electric plant	Basic.
8835	do	Bedford.
8837	do	Chase City.
8838	do	Danville.
8838-1	do	Dayton.
8839	do	Farmville.
8840	do	Franklin.
8842	do	Riverton.
8843	do	Gordonsville.
8844	do	Harrisonburg.
8845	do	Lawrenceville.
8846	do	Manassas.
8847	do	Martinsville.
8848	do	Richmond.
8849	do	Salem.
8850	do	Shenandoah.
8851	do	Staunton.
8852	Giles Power Co	Narrows.
8853	New York, Philadelphia & Norfolk Railroad	Cape Charles.
8854	Newport News & Hampton Railway, Gas & Electric Co	Hampton.
8857	Norfolk Southern Railroad Co	Bayville.
8858	North River Electric Co	Bridgewater.
8812	Nottoway Light & Power Co	Crewe.
8860	Old Dominion Power Co	Dorchester.
8861	Onancock Light & Power Co	Onancock.
8862	Orange Light Co	Orange.
8863	Peninsula Light & Power Co	Tasley.
8865	Peoples Light, Heat & Power Corporation	West Point.
8866	Petersburg, Hopewell & City Point Railway Co	Petersburg.
8867	Prince George Electric Light & Power Co	Hopewell.
8868	Radford Water Power Co	Radford.

TABLE 100.—*Electric-power companies engaged in public service in the States in which the superpower zone is situated*—Con.

Virginia—Continued.

No.	Operating company.	Station.
8869	Rappahannock Electric Light & Power Co.:	
	A	Steam, Fredericksburg.
	B	Hydroelectric, Fredericksburg.
8871	Municipal electric plant	Richland.
8871-1	Richmond-Ashland Railway Co	Richmond.
8872	Richmond & Chesapeake Bay Railway Co	Do.
8876	Riverside Light & Power Co	Waynesboro.
8877	Roanoke Railway & Electric Co.:	
	A	Niagara.
	B	Roanoke.
8880	Rural Retreat Power Co	Rural Retreat.
8881	Shenandoah River Light & Power Corporation	Luray.
8807	Shenandoah Traction Co	Staunton.
8882	Smithfield Light & Power Co	Smithfield.
8883	South Boston Power Co	South Boston.
8884	South Hill Manufacturing Co	South Hill.
8885	Spottsylvania Power Co	Fredericksburg.
8886	Stanley Milling Co	Stanley.
8887	Staunton Lighting Co	Staunton.
8889	Tazewell Electric Light & Power Co	Tazewell.
8890	Tazewell Street Railway Co	Do.
8890-1	Victoria Ice, Light & Power Co	Victoria.
8891	Valley Light & Power Co	Woodstock.
8892	Virginia Alberene Corporation:	
	A	No. 1, Schuyler.
	B	No. 2, Schuyler.
	C	No. 3, Schuyler.
8898	Warrenton Electric Light & Power Co	Warrenton.
8899	Washington & Old Dominion Railroad Co	Rosslyn.
8899-1	Weyers Cave Light & Power Co.:	
	A	Rockland.
	B	Grottoes.
8899-2	Woodstock Electric Light & Power Co	Woodstock.
8899-3	Waverly Light & Power Co	Waverly.

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